

AD-A035 311

NAVAL RESEARCH LAB WASHINGTON D C SHOCK AND VIBRATION--ETC F/G 20/11
THE SHOCK AND VIBRATION DIGEST. VOLUME 8, NUMBER 12.(U)
DEC 76

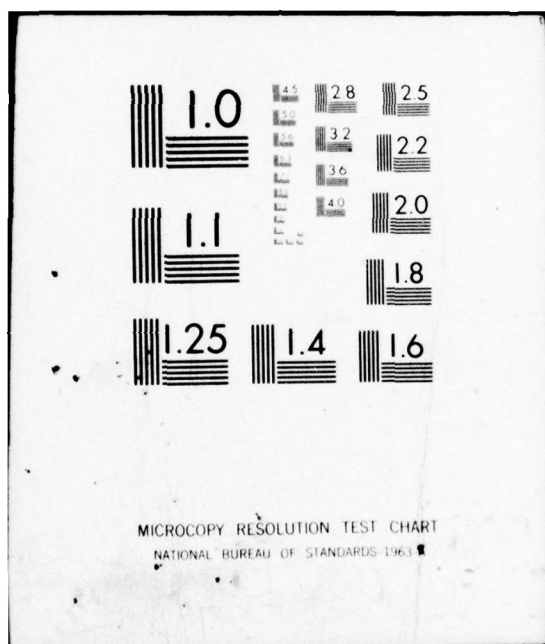
UNCLASSIFIED

NL

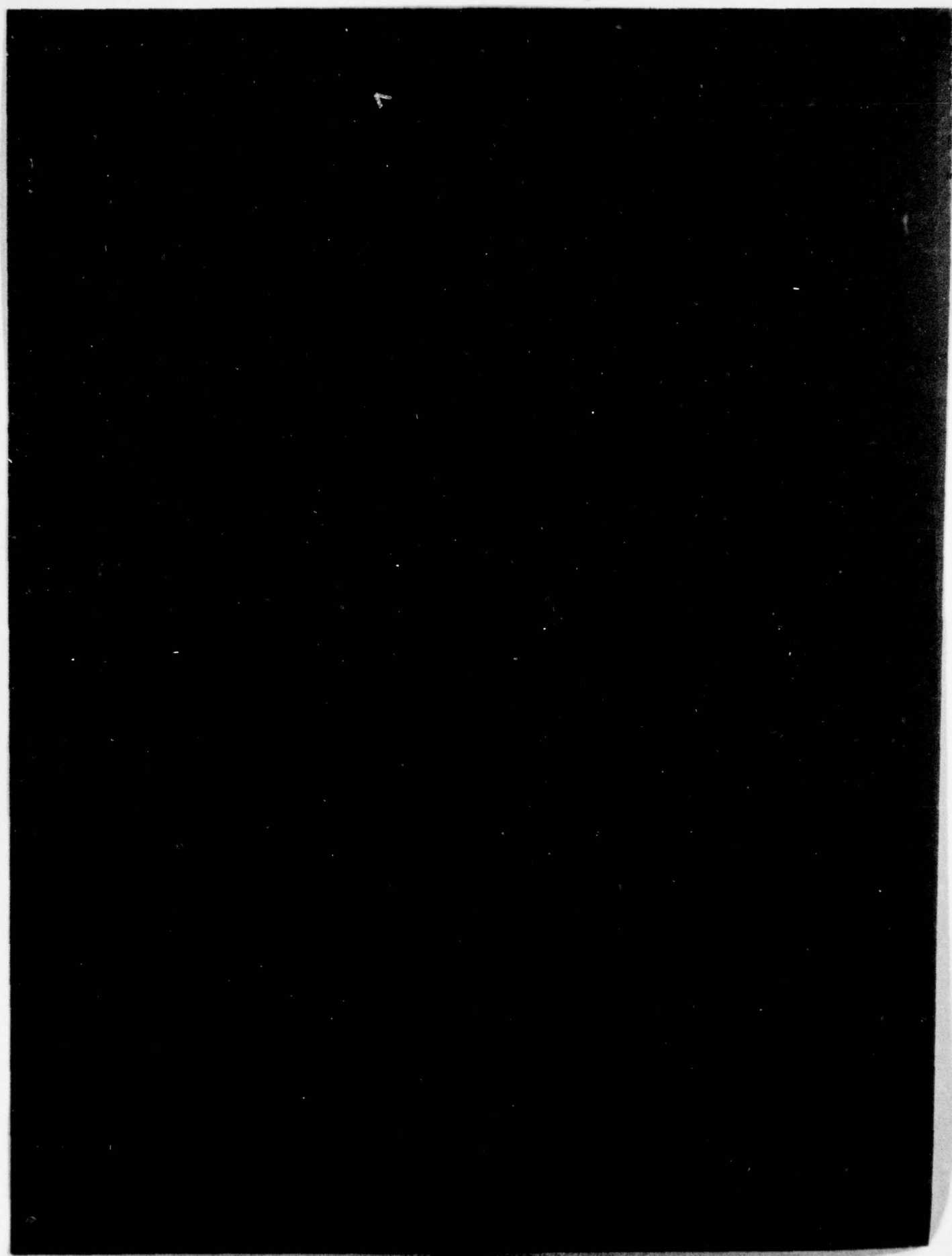
1 of 2

AD
A035311

BLANK
PAGE



ADA035311



DIRECTOR NOTES

With this issue, we are completing our eighth year of publication. During the past year we have seen significant composition improvement. Dr. Eshleman and the Vibration Institute are to be congratulated for producing consistently excellent copy. Unfortunately, some of the issues have been spoiled a bit by less than desirable printing quality. We are now trying to solve this problem.

The 47th Symposium is now history, and very successful history indeed. Thanks is due to our host, The Defense Nuclear Agency, principally represented by Dr. Eugene Sevin, who was instrumental in organizing the excellent opening session. Commendations are due for the SVIC staff--Rudy Volin, Gordan Showalter, and Barbara Szymanski--who carried out the on-site responsibilities. Special thanks to Carol Healey who minded the store at home. She is like the astronaut who goes to the moon, but must remain in orbit while the others land. A special fond "thank you" to my wife, Sallie, who managed the well received program for the ladies in attendance. I, as well as the ladies, appreciated her volunteering to fill this need.

We look forward to another useful year of service. Until then, I extend to all readers my very sincere wishes for a happy Holiday Season and a prosperous New Year.

H.C.P.

EDITORS RATTLE SPACE

THE PROLIFERATION OF "NONSTANDARD DATA"

I had occasion to take part in several informal conversations during the recent 47th Shock and Vibration Symposium. The conversations revolved about an increasingly troublesome problem: the validity of physical data. The problem parallels the development of computer-implemented data storage banks. I am not saying that most of the data are no good. Rather, there has been inadequate documentation. Standard test procedures are non-existent. There is thus no way to describe the exact conditions under which data have been taken -- nor can the limitations and applicability of the data be stated. Many engineers must use data from the literature to characterize physical phenomena. They are understandably apprehensive about applying data that may have been haphazardly gathered and then deposited in a computer data bank. The use of such data in the design process could have disastrous consequences. Unfortunately, the design engineer is not even aware of the potential misapplications that could occur.

The American Society of Testing Materials (ASTM), the American National Standards Institute (ANSI), and the trade associations have of course done their share in developing standard procedures for data collecting and recording. It is a truism, however, that the data takers far outnumber the standards workers!

The question of nonstandard data arose at the Symposium when it was noted that a standard on material and component damping characterization is needed. Researchers and practicing engineers alike admit that most of the profusion of damping data now appearing has limited application to problems other than those for which the data were taken.

My view is that, somehow, more engineers should be persuaded to be active in the development of standards -- particularly in data acquisition. It is a fact of life today that engineers are forced to seek direct solutions; there can thus be no investment of manpower in secondary effort (payable years later). It appears that this lack of foresight could force us, in the near future, to discount much of the available published data for other than specified problems. Such a situation can be avoided by increasing our efforts in standards activity. Computer analysts complain to me that no damping data exists. In my opinion, they should take the time to define what they need; then the experimentalists could collect meaningful data in an organized and rational manner.

In summary I believe that every engineer has an obligation to be aware of standards activity: the designer should define the data he needs; the analyst should outline a form for the data that meshes with his analytical techniques; and the experimentalist should standardize data taking and range of applicability.

This concludes the eighth year of publication of **The Shock and Vibration Digest**. The editorial staff of the DIGEST wishes to make this journal as useful to you as possible. Your comments on means for improving it are solicited.

R.L.E.

VIBRATION CONDITION MONITORING TECHNIQUES FOR ROTATING MACHINERY

Brian Dawson*

Abstract - This paper reviews vibration monitoring techniques currently available for rotating machinery. Applications of these techniques to bearings and gears are described.

Condition monitoring of rotating machinery is increasingly being used in preventive maintenance. Because such monitoring is based on the condition of the machine -- commonly referred to as on-condition or condition-based maintenance -- rather than a pre-determined maintenance interval. The technique requires reliable determination of the condition of machinery during operation. Various parameters are used; for example, power and efficiency; oil, coolant, and bearing temperatures; oil pressure and contamination; and vibration and noise measurements. A discussion of the complete range of monitoring techniques is beyond the scope of this article. It should be clearly recognized, however, that vibration monitoring techniques comprise only part of a condition monitoring program and that detailed study and appraisal of all possible techniques is necessary before a program is begun [1-5].

TYPES OF VIBRATION MONITORING TECHNIQUES

The simplest vibration condition monitoring technique is the measurement of the overall root mean square level of velocity or acceleration at selected points. The vibration level, called a discriminant, is an indicator of the condition of the machine. Comparison of the measured level with values on a standard vibration severity chart allow assessment of the machine [6-8]. These general tables do not provide for the dynamic response of specific machines, but they are useful in assessing the acceptability of machine operation and indicating impending failure.

Downham and Woods [9] developed an impedance testing technique that can be used with vibration severity tables. This technique allows a relatively realistic interpretation of changes in vibration levels and modification of operational criteria in accordance

with the dynamic stiffness of the machine bearings.

Another technique is to measure shaft displacement using noncontacting sensors at 90° angles from each other. The resulting Lissajous and time domain signals give an indication of shaft unbalance, misalignment, and subrotational instability. Signals from noncontacting transducers mounted with respect to the bearing housing should be interpreted carefully [10].

The above techniques are useful, but they provide only a limited amount of diagnostic information. (Diagnosis has been defined as the art or act of identifying the condition of a machine from its signs or symptoms [11].) The intent is to determine the condition of the machine through the analysis of its vibration without the necessity for visual inspection.

One approach that provides some diagnostic information involves measuring vibration levels in octave or one-third octave bands for one or more similar machines in the 'as new' condition. Departures from these baseline data can be used as criteria for assessing the condition of operating machinery. This technique, based on full octave band vibration measurements, has been successfully used by the Canadian Navy [12] to monitor the main propulsion and principal auxiliary equipment installed in all classes of the destroyer fleet and the submarine and maintenance support vessel equipment associated with weapons and operational systems. Techniques that can be used for one-off assessments of machine condition are called condition checking techniques.

If baseline data and failure experience are not available, machinery can be monitored either continuously or at known intervals. A decision on the condition of the machine is based on the trend of the discriminant; that is, whether or not the vibration level is increasing. The rate of change of the discriminant before failure must be slow enough to

* Professor, Division of Engineering, The Polytechnic of Central London, London W1M 8JS, England

allow prediction of an impending failure and shut-down of the machine, however. Data obtained by the Canadian Navy [13] indicate that the mean level of a signature component as a function of time is generally a straight line having a slight positive slope for 75% of a machine's useful life; after this point the slope rises exponentially to the point of failure. The interval from the beginning of the exponential increase to failure, called the lead time, makes trend monitoring a viable maintenance procedure.

It is perhaps worth mentioning that, although condition monitoring resulting in on-condition maintenance is the prime objective of condition monitoring techniques, it has been argued [4] that the techniques encompass much more; for example, condition monitoring should be used during machinery installation. Condition monitoring techniques should also have an important role in product development [14] and quality control.

The number of diagnostic techniques for condition monitoring is large; a useful chart of possible transducers, processing procedures, and discriminants has been published [15]. Investigations into the use of vibration signature analysis techniques for diagnosis of power trains of army helicopters resulted in the division of discriminant selection into two types: condition monitoring procedures based on pattern recognition techniques and those dependent on mechanical techniques [15]. Pattern recognition techniques utilize statistical differences to determine discriminants; a disadvantage, however, is the large amount of data required before the techniques can be considered valid. These data are not always presently available, but it is hoped that increasing interest in condition monitoring will stimulate the establishment of data banks of vibration information for good and bad machines. Pattern recognition techniques developed for gears and bearings have been briefly described [15], and a number of investigators [16-20] have been working on the development of pattern recognition techniques for fault diagnosis.

Mechanical diagnostic techniques select discriminants on the basis of dynamic analysis, which provides information concerning such characteristics of the system as component natural frequencies, rotational

whirl frequencies, forces, deflections, and accelerations. Time domain signal signatures from the measurement transducer must be transformed into the frequency domain before frequency components can be used as discriminants. A simple technique for achieving this transformation is to pass the vibration time domain signal through a tunable band-pass filter. The individual frequencies isolated depend on the bandwidth and shape of the filter and the particular frequency discriminants obtained. A manually tunable band-pass filter is a useful and inexpensive approach [21].

Often, however, a number of discriminants within a small frequency range must be monitored; in this case an analog band-pass filter technique is time consuming. Fortunately, this problem has been overcome by the development of the real time spectrum analyzer (RTA); frequency spectra can be obtained in a few milliseconds. Digital time compression of the vibration time domain signal allows very rapid determination of spectra. The spectra either can be permanently recorded on an X-Y plotter or processed further with a digital computer. Ensemble averaging of the spectra allows the enhancement of signals buried in noise.

APPLICATION OF CONDITION MONITORING TO ROTATING MACHINERY

Components of rotating machinery to which condition monitoring has been applied include rolling bearings and gear trains.

Bearings

The failure of ball and roller bearings -- assuming proper design and maintenance -- usually results from subsurface fatigue caused by the high cyclic contact load between the balls or rollers and the race. Surface fatigue spalls or any other surface defect disturb the rolling motion. The result is growth of the defect area, an increase in friction, and ultimately an increase in wear rate. The defect area eventually becomes so large that the bearing no longer functions properly, and serious damage occurs.

Local defects in the inner or outer race of a bearing are hit by the ball each time it passes over them. A surface defect on the ball will also strike the

inner or outer race. The rate at which these impacts occur depends upon bearing speed and location of the defect. Formulas are available to calculate these rates [22, 23]. In addition, vibrations corresponding to the waviness of the ball and races, as well as high frequency resonant frequencies of the races, can be calculated [24]. The vibration time domain spectrum of a local defect of the ball or race is a repetitive ringing transient response. The actual response pattern depends upon the structural transfer function between the source and the measurement point. Diagnostic techniques based on this type of response include narrow-band low-frequency analysis and high-frequency analysis.

Narrow-band low-frequency analysis depends upon the fact that the race pass frequencies and their harmonics become prominent as a bearing fault develops. With properly functioning bearings the shaft frequency and its harmonics dominate. A successful application of the low frequency technique has been reported [23], but use of the method is limited because noise discrimination is poor in the presence of other mechanical signals. This analysis is therefore suitable only for detecting faults in simple rotating assemblies in which the vibration is caused by the bearing or for quality control purposes in special ball bearing test rigs [25].

High-frequency analysis of the ring frequencies associated with bearing housing response to local faults appears to be much more sensitive to the bearing fault condition and is not sensitive to background noise. A ringing frequency of a bearing housing indicates a bearing fault. Several investigators have developed successful diagnostic techniques based on ringing frequency [26 - 31]. An instrument called a shock pulse meter monitors bearings on the basis of the ringing principle. The ring frequency is the natural frequency of the measurement transducer (≈ 38 KHz). The shock pulses produced by a defect are detected by the accelerometer. The bearing condition is assessed by measuring the rate of shock emissions relative to the amplitude of the pulse. The detection of defects by measurement of acoustic emissions produced by growing cracks is a developing science, and it is already being applied to bearings [26, 32].

Monitoring techniques for detecting bearing faults have been directed at local defects. Faults described as distributed effects-e.g., misalignment, lack of roundness, unequal ball diameters-must, also be detected, however, especially in quality control situations. Vibration monitoring has been used to predict defects in gyros for spacecraft [27]; vibration signatures were predicted from mathematical models. The 'initial' bearing defects were modeled as disturbances of the force pattern so that the dynamic radial deflection at the stationary bearing ring could be determined. The solution involved several series of modulated tones; frequencies and modulation patterns depend on the initial defect. Seven out of eight known distributed defects were detected and identified correctly.

Gears

The dynamic characteristics and failure modes of gears are so radically different to bearings that a new set of mechanically related diagnostic techniques have been developed. A pair of mating gears running at constant speed and load generate a periodic vibration signal at the meshing frequency. Assuming perfect gears, the meshing vibration signal responses would not change during a complete rotation of the gear. In practice, the mesh time domain vibration response depends on a number of factors: gear profile; load; speed; stiffnesses of gear, gear tooth, shaft, and bearing; and eccentricity. The condition of gears depends upon the way in which these parameters affect the overall mesh vibration response characteristic. The nature of the excitation sources at tooth contact and the identification of tooth contact frequency components and their sidebands for spur and helical gearing have been presented [34].

Gear defects used in condition monitoring have been classified as local and distributed defects [27]. Local defects are defined as defects that occur on one or more teeth but are not uniformly distributed among the teeth. Examples are cracked, deformed, or scored teeth. A local defect manifests itself only when the damaged tooth is in mesh. Detection is thus relatively simple: inspect the time domain signal of a complete revolution of the gear; if extraneous noise is reduced by signal averaging during one revolution of the relevant gear wheel, the mesh of a damaged tooth can easily be detected.

A distributed defect causes a response that occurs throughout the complete meshing cycle. A common example is nonuniform load distribution on the teeth due to eccentricity of a gear shaft. Loading varies during one revolution of the gears; the resulting mesh time domain signal appears as a carrier frequency at the mesh rate, and amplitude modulation occurs at the rotational frequency. Periodic variations in pitch error and torque fluctuations can also cause both amplitude and frequency modulation of the mesh frequency [34, 35].

A gear condition monitor based on a time domain signal summation (signal averaging) technique has been described [27]. Local defects were determined by a crest factor analysis. (In normal gear tone, with all tooth meshes equal in shape and amplitude, there is a specific ratio of peak to amplitude, tooth mesh response changes are reflected by a change in the ratio.) Distributed defects were indicated by the percentage modulation of the gear tone. The application of the monitor to a complex gear assembly has been described, and fault conditions were successfully detected and interpreted [27].

Investigators have demonstrated that distributed defects in gear boxes give rise to modulation of the tooth meshing vibration and that the modulation can be detected in the frequency spectrum [36, 37]. The detection of sidebands caused by frequency modulation can be aided by the application of the spectrum technique, which has been successfully applied to gear vibration [38].

Steward has summarized gear diagnostic techniques [47]. He interprets gear condition by analyzing a narrow-band power spectrum, a time domain signal summation based on an average period of one revolution of the gear under study, and wear trend based on a logarithmic difference plot between relevant components of the measured spectrum and a baseline spectrum of the new assembly. Secondary transformation of the time domain signal average results in a dynamic error signature (which essentially indicates abrupt changes in the character of the time domain signal). An instantaneous frequency plot is also useful in identifying fault conditions.

Narrow-band spectrum-analysis of a vibration time domain signal can be used to indicate faults due to

unbalance, oil whirl, misalignment, mechanical looseness, seal rubbing, belt slip, and structural resonance. Useful diagnostic charts are available [21, 39].

It has been said that condition-based maintenance is likely to become the accepted description of a rational new approach to preventive maintenance [40]. Condition monitoring techniques must be related to maintenance planning and hence to the uncertainty associated with the maintenance program. The basic problems involved in handling condition monitoring systems include deciding whether or not to test and establishing analytical techniques for dealing with uncertainty. There is also uncertainty in interpreting test results, particularly with regard to the analysis of noise and vibration measurements [41].

CONCLUSION

A number of vibration analysis techniques are now available for detecting and identifying defects in rotating machinery. Most of the work to date has concentrated on developing mechanical diagnostic techniques. For large organizations with the capability for building data banks, pattern recognition techniques may be of value in the future.

REFERENCES

1. O'Hara, J.P., Sarkis, A.B., and Kennedy, W.A., "Equipment Protection through Customized Oil Analysis," Soc. Automatic Engr., N.Y.
2. Rogers, L.M., "The Application of Thermography to Plant Condition Monitoring and Energy Conservation," BSC Tech. Rep. TB/TH/71. Corporate Development Laboratory, BCC, Sheffield, Engl. (1974).
3. Gadd, P., "Diagnostic Aids for Oil Lubricated Systems," SEEEO, London (1975).
4. Steward, R.M., "Assessing the General Condition of Rotating Machinery," SEEEO, London (1975).

5. Collacott, R.A., "Mechanical Failure - Diagnosis and Monitoring," C.M.E. (July 1976).
6. "Criteria for Assessing Mechanical Vibrations of Machines," VDI Z., Rep. No. VDA 2056 (Oct 1964).
7. "A Basis for Comparative Evaluation of Vibration in Machinery," BS 4675, British Standards Institute, London (1971).
8. "Mechanical Vibration of Machines with Operating Speeds from 10-200 rev/s - Basis for specifying evaluation standards," ISO 2372 International Standards Organization, Geneva (1974).
9. Downham, E. and Woods, R., "The Rationale of Monitoring Vibration on Rotating Machinery in a Continuously Operating Process Plant," ASME Paper No. 71-VIBR-96, J. Engr. for Indus., Trans. ASME (1971).
10. Mitchell, J.S., "Vibration Analysis - Its Evolution and Use in Machinery Health Monitoring," SEECO, London (1975).
11. Schleroth, F.H. (ed.), "Glossary of terms used in the identification and prediction of mechanical failures," Mechanical Failure Prevention Group, MFPG Interim Rep. No. 1., Office of Naval Res., Arlington, VA (1971).
12. Xistris, G.D. and May, R.G., "An Automated Real Time Full Octave Band System for Shipboard Vibration Measurement," 20th Intl. Instrumentation Symposium, Albuquerque, NM (1974).
13. Sankar, T.S. and Xistris, G.D., "Failure Prediction through the Theory of Stochastic Excursions of Extreme Vibration Amplitudes," ASME Paper No. 71-VIBR-60 (1971).
14. Dawson, B. and Duncan, P.E., "Diagnostic Vibration Tests on a High Pressure Water Pump," Technical Memo CMI Sound and Vibration Services Ltd., London (1975).
15. Houser, D.R., Drosjack, M.J., and Hogg, G.W., "Vibration Diagnostics in Helicopter Power Trains," AGARD Conf. Proc. No. 165.
16. Becker, P.W., "Recognition of Patterns, Copenhagen, Denmark, Polyteknisk Forlag (1968).
17. Cortina, E. et al, "Pattern Recognition Techniques Applied to Diagnostics," SAE Rep. 7000407 (1970).
18. Hankley, W.J. and Merrill, H.M., "A Pattern Recognition Technique for System Error Analysis," IEEE Trans. Rel., R-20 (Aug 1971).
19. Page, J., "Recognition of Patterns in Jet Engine Vibrations Signals," IEEE Pub. No. 16C51.
20. Pau, L.F., "Diagnosis of Equipment Failures by Pattern Recognition," IEEE Trans. Rel. R-23 (3) (1974).
21. B & K Application Note, "Notes on the use of vibration measurements for machinery condition monitoring."
22. Palmgren, A., Ball and Roller Bearing Engineering, Section 24, S.H. Burbank, Philadelphia (1959).
23. Ballas, T.A., "Periodic Noise in Bearings," Natl. Powerplant Mtg., Paper No. 690756, Cleveland, OH (Oct 1969).
24. Gustafson, O.G. et al. "Study of Vibration Characteristics of Bearings," AD 132-979, SKF Industries.
25. Babkin, A.S. and Anderson, J.J., "Mechanical Signature Analysis of Ball Bearings by Real Time Spectrum Analysis," J. Environ. Sci. (Jan/Feb 1973).
26. Balderston, H.L., "The Detection of Incipient Failure in Bearings," Materials Evaluation, pp 121-128, (June 1969).
27. Weichbrodt, B. and Smith, K.A., "Signature Analysis - Non-intrusive Techniques for Incipient Failure Identification Application to Bearings and Gears," AIAA Space Simulation Conf. (Sept 1970).

28. Cornich, J.F. and Roger, L.M., "A Review of Low and High Frequency Vibration Analysis Techniques," Machine Health Monitoring, 23 and 24, SEECO, London (1975).
29. Kellum, G.B., "Investigation of Machinery Vibrations Induced by Defective Rolling Element Bearings," ASME Paper No. 72-PEM-25 (1972).
30. Burchill, R.F., "Resonant Structure Techniques for Bearing Fault Analysis," Paper presented at 18th Mtg. Mech. Failures Prevention Group, Gaithersburg, MD (Nov 1972).
31. Darlow, M.S. and Badgley, R.H., "Early Detection of Defects in Rolling Element Bearings," Soc. Automatic Engr. Paper No. 750209 (1975).
32. Howard, P.L., "Application of Shock Pulse Technology and Vibration Analysis to Rolling Bearing Condition Monitoring," Proc. 20th Intl. Instrumentation Symp., Albuquerque, NM (1974).
33. James, R. et al, "Acoustic Instrumentation Technique Predicts Mechanical Failures," Oil Gas J. (Dec 1973).
34. Kohler, H.K. et al, "Dynamics and Noise of Parallel-Axis Gearing," Gearing in 1970, IMechE.
35. Mitchell, L.D. and Lynch, G.A., "Origins of Noise," Machine Design (May 1969).
36. Thompson, R.A. and Weichbrodt, B., "Gear Diagnostics and Wear Detection," ASME Paper No. VIBR-10 (1969).
37. White, C.J., "Detection of Gear Box Failure," Workshop in on-condition maintenance. Univ. Southampton (1972).
38. Randall, R., "Analysis Techniques for Machine Health Monitoring," B & K Lecture No. 260E.
39. Kinne, H.M., "Monitoring Machine Vibration," Automation (July 1969).
40. Special bulletin on Condition Monitoring, Maintenance Management, (summer 1976).
41. Stewart, R.M., "The Role of Uncertainty in the Design of Condition Monitoring Systems," Workshop on Condition Monitoring, ISUR, (1972).

LITERATURE REVIEW

survey and analysis
of the Shock and
Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

In this issue of the DIGEST Alan Hannibal's article on *Modeling of Vibrating Systems* is continued. He gives an overview of approximate methods, mechanical impedance and mobility, transfer matrix method, finite element methods and bond graphs.

In the second review article, Professor Robert Plunkett of the University of Minnesota briefly describes recent developments in instrumentation used to measure shock and vibration.

MODELING OF VIBRATING SYSTEMS - AN OVERVIEW

Part II. Approximate Methods, Mechanical Impedance and Mobility, Transfer-Matrix Method, Finite Element Methods, and Bond Graphs

A. J. Hannibal*

A number of prominent modeling methods are presented in capsule form. The "type" of modeling technique is emphasized rather than details of the method. The references have been divided into sections relating to the modeling methods.

APPROXIMATE METHODS

Approximate methods are used to model distributed systems within a finite number of degrees of freedom. Approximate methods are used for at least one of three reasons.

- For cases of nonuniformity in which the governing equations are difficult, perhaps impossible, to solve in closed form
- For reducing a distributed system to standard matrix form (see equation (21)), thereby making the equations compatible with discrete elements in the system
- For analyses over a limited frequency range

The approximate methods in common use include the assumed-modes method, lumped-parameter method, and the influence coefficient method. The assumed-modes method is the most flexible because it is an energy method, and generalized distributed coordinates can be used. The others usually involve geometric coordinates.

In the assumed-modes method, the response of the distributed system is assumed to be of the form

$$y(\vec{x}, t) = \sum_{i=1}^n \phi_i(\vec{x}) q_i(t) \quad (18)$$

where $q_i(t)$ are time-dependent generalized coordinates and $\phi_i(\vec{x})$ are admissible functions in terms of the spatial coordinates, \vec{x} . That is, the functions satisfy all the geometric boundary conditions and all the criteria for differentiation. In cases of nonuniformity, either the eigenfunctions of the uniform case or a polynomial are used as admissible functions.

Substitution of equation (18) into the integral formulation of the kinetic and potential energies of

the continuous system yields the energy expressions, given by equations (19) and (20). These expressions are typical of a discrete n-dimensional system.

$$T = \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n m_{ij} \dot{q}_i \dot{q}_j \quad (19)$$

$$V = \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n k_{ij} q_i q_j \quad (20)$$

In these equations m_{ij} depends on the mass distribution and the admissible functions $\phi_i(\vec{x})$. The mass matrix $[m_{ij}]$, when derived in this fashion, is referred to as the consistent mass matrix [16]; k_{ij} is dependent on the stiffness distribution and the admissible functions.

The equations of motion can be derived directly from equation (11) and are of the matrix form

$$[m_{ij}] \ddot{\vec{q}} + [k_{ij}] \vec{q} = \vec{F} \quad (21)$$

In addition to the assumed-modes method are Galerkin's method and the Collocation method. Both derivations are based on an error function associated with the equilibrium equation. All of these methods have been discussed [17].

MECHANICAL IMPEDANCE AND MOBILITY

Impedance and mobility methods have not received the attention they deserve. The emphasis on noise pollution has stimulated renewed interest, however, because complex structures can radiate acoustic energy over a range from several hundred to several thousand Hertz. Impedance methods are used to reduce such systems to a manageable level.

Consider that the linear, nonrigid structure in Figure 3 is acted upon by n sinusoidal forces, either excitation or reaction, having the same frequency. The

* Advanced Systems Dept., Lord Kinematics, Erie, PA 16512

mobility equations that define the structure are

$$\begin{aligned} v_1 &= m_{11}F_1 + m_{12}F_2 + \dots + m_{1n}F_n \\ v_2 &= m_{21}F_1 + m_{22}F_2 + \dots + m_{2n}F_n \\ &\vdots \\ v_n &= m_{n1}F_1 + \dots + m_{nn}F_n \end{aligned} \quad (22)$$

or

$$\vec{V} = M\vec{F} \quad (23)$$

M is referred to as the mobility matrix, and the elements m_{ij} are complex quantities. The diagonal elements m_{ij} are called driving point mobilities, and the off-diagonal elements $m_{ij}(i \neq j)$ are called transfer mobilities. Equation (23) essentially characterizes the entire structure at n discrete points; that is, if Figure 3 represents a nonrigid foundation upon which a vibrating machine is to be placed, only the force-velocity relationship at the points of attachment need be known.

The inverse of the mobility matrix, M^{-1} , is called the impedance matrix.

In the matrix characterization of mechanical structures, mobility is more suitable than impedance. The reason is that mobility does not require "blocked" points and, therefore, can be expanded or contracted without disturbing previous measurements or calculations. A detailed discussion has been published [18].

Closely related to mobility and impedance are the four-pole parameters, which can be used to analyze mechanical systems having a single input terminal and a single output terminal (see fig. 4).

In equation form, Figure 4 can be characterized by

$$\begin{Bmatrix} F_1 \\ V_1 \end{Bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{Bmatrix} F_2 \\ V_2 \end{Bmatrix} \quad (24)$$

from which

$$\begin{aligned} \alpha_{11} &= F_1/F_2 \mid V_2 = 0 \\ \alpha_{12} &= F_1/V_2 \mid F_2 = 0 \\ \alpha_{21} &= V_1/F_2 \mid V_2 = 0 \\ \alpha_{22} &= V_1/V_2 \mid F_2 = 0 \end{aligned} \quad (25)$$

where $v_2 = 0$ implies that the output terminal is blocked and $F_2 = 0$ implies that it is free. From equation (25) it is apparent that α_{12} is an impedance, α_{21} is a mobility, and α_{11} and α_{22} are transmissibilities. The four parameters are usually frequency dependent complex quantities. Fortunately, they are not dependent on the presence of any other mechanical system.

From the Theorem of Reciprocity, it can be shown that

$$\alpha_{11}\alpha_{22} - \alpha_{12}\alpha_{21} = 1 \quad (26)$$

so that never more than three of the four-pole parameters are needed to specify the system completely. In the case of a symmetrical mechanical system, it can also be shown that

$$\alpha_{11} = \alpha_{22} \quad (27)$$

so that only two of the four-pole parameters is needed to specify the system. Snowdon [19] presents a systematic approach to four-pole parameters; Sakata [20] applies the parameters to vibration isolation of the engine/transmission from the body of a vehicle in order to reduce noise in the passenger compartment.

In the treatment of vibration isolation between nonrigid machines and nonrigid foundations as depicted on Figure 5, Soliman and Hallam [21] neatly blend mobility representations of the machine and foundation with four-pole characterizations of the isolators.

Even though mechanical impedance and mobility measurements can theoretically be utilized to characterize complex structures using a number of discrete nodes, they are not problem free. Extreme care in the

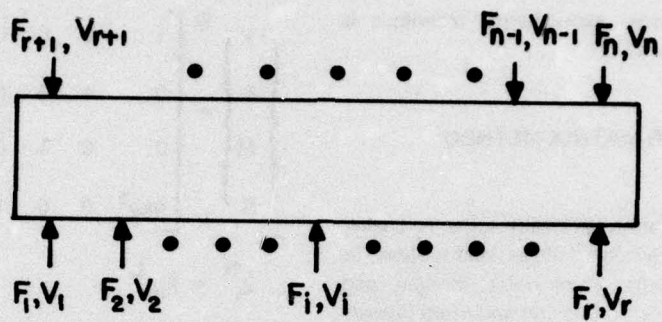


Figure 3. Nonrigid Structure



Figure 4. Mechanical System

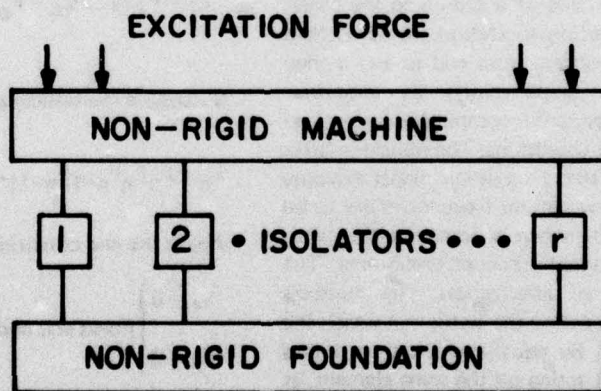


Figure 5. Nonrigid Mechanical System

administration of proper experimental technique is required to avoid errors [22].

TRANSFER-MATRIX METHOD

The transfer-matrix method is ideally suited to chain-like model systems. Systems such as beams, diesel- or turbine-generator shafts, crankshafts, straight and branched rotor systems, composites and multi-layered media such as soils [36, 37] fall into this category.

The foundation for the transfer-matrix method, referred to as the Myklestad-Prohl Method, was developed in the mid-1940s by N.O. Myklestad [38] to analyze airplane wings and other types of beams and by M.A. Prohl [39] to analyze flexible rotors. Both men directed their work toward the calculation of undamped natural frequencies of planar systems. Lund [40] extended their work in analyzing the orbital response of unbalanced flexible rotors in fluid film bearings. He further extended the method [41] to determine stability and damped critical speeds of a flexible rotor in fluid-film (plain cylindrical and tilting-pad journal) bearings.

The transfer-matrix method is a linear, lumped-parameter analysis in which a distributed system is divided into concentrated mass points, or stations, connected by massless elastic segments. Transfer, or point, matrices that equalize forces and moments are derived from one side of a station to the other; and matrices from station to station are called field matrices. The entire system from end to end is then accumulated into a single matrix by successive multiplications. The system is completely determined by applying only end conditions. The transfer-matrix method can be elucidated via a simple planar example for which the first few natural frequencies are to be determined. Figure 6a shows a homogeneous cantilever beam with a variable cross-sectional area. The dashed lines imply an idealization. The numbers 1, 2, ..., n in Figure 6b define the stations at which the mass is concentrated. By equalizing the shear forces (S) and moments (M) acting on the mass element, as shown in Figure 6c, the point matrix shown in equation (28) is derived.

$$\begin{Bmatrix} -y \\ \theta \\ M \\ S \end{Bmatrix}_i^R = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ m\omega^2 & 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} -y \\ \theta \\ M \\ S \end{Bmatrix}_i^L \quad (28)$$

or

$$Z_i^R = P_i Z_i^L$$

Equalize forces and moments as shown in Figure 6d and apply elementary strength of materials principles to derive the field matrix for the massless beam element, equation (29).

$$\begin{Bmatrix} -y \\ \theta \\ M \\ S \end{Bmatrix}_i^L = \begin{bmatrix} 1 & l & l^2/2EJ & l^3/6EJ \\ 0 & 1 & l/EJ & l^2/2EJ \\ 0 & 0 & 1 & l \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} -y \\ \theta \\ M \\ S \end{Bmatrix}_{i-1}^R \quad (29)$$

or

$$Z_i^L = F_i Z_{i-1}^R$$

Apply equations (28) and (29) consecutively from the fixed end to the free end

$$\begin{aligned} Z_1^L &= F_1 Z_0^R; Z_1^R = P_1 Z_1^L; \\ Z_2^L &= F_2 Z_1^R \dots Z_n^L = F_n Z_{n-1}^R; Z_n^R = P_n Z_n^L \end{aligned} \quad (30)$$

Successive multiplication yields

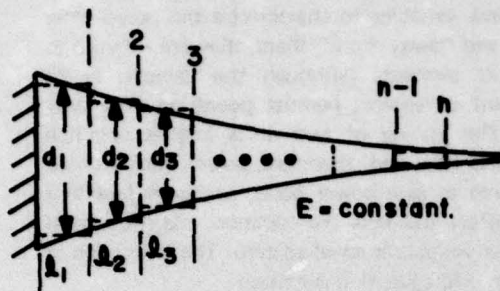
$$Z_n = P_n F_n P_{n-1} F_{n-1} \dots P_2 F_2 P_1 F_1 Z_0 \quad (31)$$

Apply the end conditions

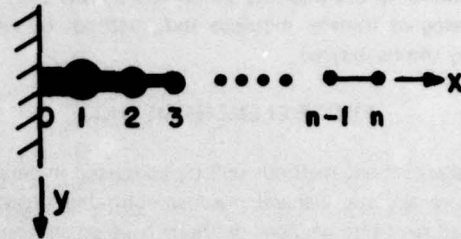
$$\left. \begin{aligned} y_0 &= 0 \\ \theta_0 &= 0 \end{aligned} \right\} \text{Fixed end and} \quad \left. \begin{aligned} M_n &= 0 \\ S_n &= 0 \end{aligned} \right\} \text{Free end} \quad (32)$$

to calculate the undamped natural frequencies from the determinant

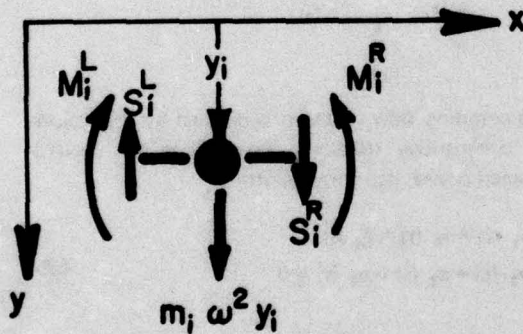
$$\begin{vmatrix} u_{33} & u_{34} \\ u_{43} & u_{44} \end{vmatrix} = 0 \quad (33)$$



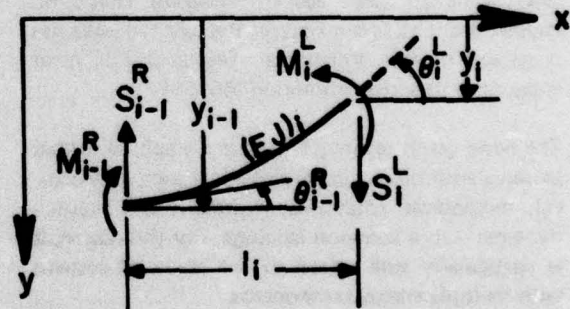
a) Planar Model of a Homogeneous Cantilever Beam of Varying Cross-Section.



b) Idealization of a Cantilever Beam.



c) Free-Body Diagram of a Mass Element, m_i .



d) Free-Body Diagram of Massless, Elastic Beam

Figure 6. Example of Transfer-Matrix Method

Although this formulation is compact, each term can be a high order polynomial of ω , requiring a numerical treatment for solution.

Included in the book by Pestel and Leckie [42] is a catalog of transfer matrices and, methods by which they can be derived.

FINITE ELEMENT METHOD

Finite element methods will be addressed in detail in future articles. General purpose computer programs based on finite element methods have revolutionized vibration analysis in general. Finite element programs can be routinely used to model rather complex vibratory systems; knowledge of how the elements are derived or assembled is not necessary. Experience is valuable, however, in element selection, grid construction, mesh density, boundary conditions, etc.... Finite element methods have allowed the reduction of complex structures to analyzable form; particularly useful are the component mode synthesis [43-46] and Guyan Reduction or "master" degrees of freedom [47, 48].

BOND GRAPHS

The bond graph approach was originally reported [54] some 25 years ago by Professor Henry M. Paynter from MIT, but only in the past ten years has it gained notable acceptance. This is due in great measure to its active promotion [55, 56].

The bond graph technique utilizes a graphical format to reduce various dynamic systems -- such as, electrical, mechanical, rotational, hydraulic, and thermodynamic -- to a common language. For this reason, it is particularly well suited to the study of systems with multiple energy components.

A few basic definitions will be applied to a single degree-of-freedom damped oscillator (Fig. 9a). Because bond graphs are basically an energy-power concept, the fundamental variables are referred to as effort (e) and flow (f) -- the product of which yields power. In mechanical systems, effort and flow are more commonly referred to as force and velocity; in electrical systems, voltage and current; and in hydraulic systems, pressure and volume flow rate.

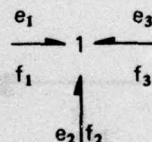
Because the three basic components of the oscillator (spring, mass, and damper) require only one pair of effort-flow variables to characterize the power flow "into" and "away from" them, they are referred to as 1-port elements (although the damper, or its equivalent a resistor, permits power to flow only into). The joining of two ports implies common effort and flow and, therefore, power; such a union is referred to as a power bond. In 3-port junctions either effort and flow are common, and the sum of the other variable is equal to zero. The 0-junction or common effort junction is written



It is defined by the following constitutive relations (using the inward-directed power sign convention)

$$\begin{aligned} e_1(t) &= e_2(t) = e_3(t) \\ f_1(t) &= f_2(t) + f_3(t) = 0 \end{aligned} \quad (34)$$

With the 1-junction or common flow junction the roles of effort and flow are interchanged.

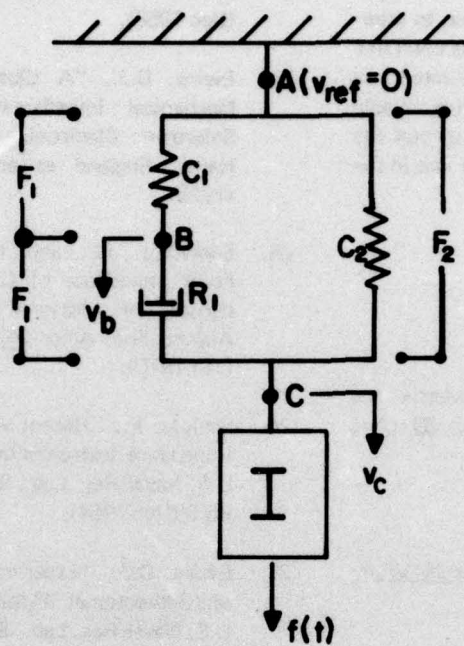


The common flow junction is defined by the following constitutive relations, again using the inward-directed power sign convention

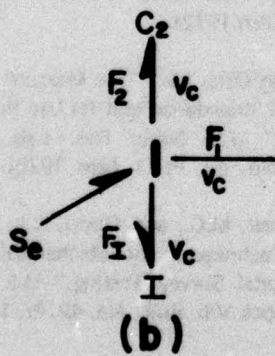
$$\begin{aligned} f_1(t) &= f_2(t) = f_3(t) \\ e_1(t) + e_2(t) + e_3(t) &= 0 \end{aligned} \quad (35)$$

Points A and C (fig. 7a) are junctions of common velocity (flow) and are represented by 1-junctions; however, as $v_{ref} \equiv 0$, point A will be ignored. The 1-junction associated with point C is shown on Figure 7b, including bonds with the spring (C_2), the mass (I), the excitation S_e (effort source), and the unbonded port (F_1, v_C). The half arrows on the port lines indicate the direction of power flow when both effort and flow are positive. Point B is a junction of

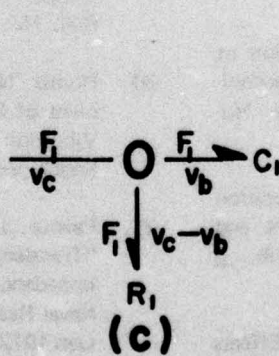
BL



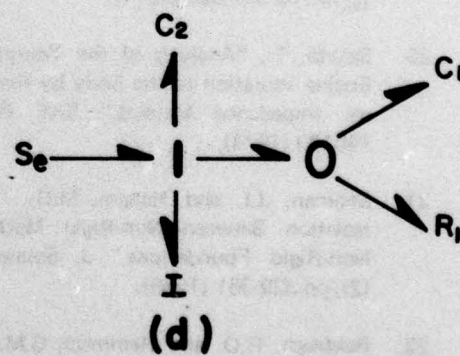
(a)



(b)



(c)



(d)

Figure 7. Bond Graph of a Damped Oscillator

common effort (force) and is modeled as a 0-junction (Fig 7c). The bond graph of Figure 7a is completed by joining the common port (F_1, v_C), as illustrated in Figure 7d. A computer program designed to interpret the graphic language of bond graphs is ENPORT [57]; the equations of motion are formulated and solved. Karnopp and Rosenberg [56] define reliable "construction methods" for bond graphs so that the inspection method need not be used, as it was in the example.

REFERENCES

General

16. Archer, J.S., "Consistent Mass Matrix for Distributed Systems," ASCE Proc., **89** (Aug 1963).

Approximate Methods

17. Meirovitch, L., Analytical Methods in Vibrations, MacMillan, London (1967).

Impedance and Mobility

18. O'Hara, G.J., "Mechanical Impedance and Mobility Concepts," NRL Report 6406 (July 1966).
19. Snowdon, J.C., "Mechanical Four-Pole Parameters and Their Application," J. Sound Vib., **15** (3), pp 307-323 (1971).
20. Sakata, T., "Analysis of the Transmission of Engine Vibration to the Body by the Mechanical Impedance Method," SAE Paper No. 740163 (1974).
21. Soliman, J.I. and Hallam, M.G., "Vibration Isolation Between Non-Rigid Machines and Non-Rigid Foundations," J. Sound Vib., **8** (2), pp 329-351 (1968).
22. Belsheim, R.O. and Remmers, G.M., "Effects of Technique on Reliability of Mechanical Impedance Measurement," U.S. Naval Res. Lab., Shock Vib. Bull., No. 34, Pt. 3 (Dec 1964).

23. Plunkett, R., ed., Mechanical Impedance Methods for Mechanical Vibrations, presented at the ASME Annual Meeting, New York (Dec 1958).
24. Ewins, D.J., "A Classified Bibliography of Mechanical Impedance," published by the Solartron Electronic Group, Farnborough, Hants, England as an individual document (1973).
25. Snowdon, J.C. and Kerlin, R.L., "Driving-Point Impedance of Cantilever Beams - Comparison of Measurement and Theory," J. Acoust. Soc. Amer., **47** (1), Pt. 2, pp 220-228 (Jan 1970).
26. Schloss, F., "Recent Advances in Mechanical Impedance Instrumentation and Applications," U.S. Naval Res. Lab., Shock Vib. Bull., No. 34, Pt. 3 (Dec 1964).
27. Ewins, D.J., "Experimental Determination of Multi-directional Mobility Data for Beams," U.S. Naval Res. Lab., Shock Vib. Bull., No. 45, Pt. 4 (June 1975).
28. Molloy, C.T., "Use of Four-Pole Parameters in Vibration Calculations," J. Acoust. Soc. Amer., **29** (7) (July 1957).
29. Ludwig, E.F., "Force Transducer Calibrations Related to Mechanical Impedance Measurements," U.S. Naval Res. Lab., Shock Vib. Bull., No. 42, Pt. 1 (Jan 1972).
30. Hunter, N.F., Jr. and Otts, J.V., "The Measurement of Mechanical Impedance and Its Use in Vibration Testing," U.S. Naval Res. Lab., Shock Vib. Bull., No. 42, Pt. 1 (Jan 1972).
31. Favour, J.D., Mitchell, M.C., and Olson, N.L., "Transient Test Techniques for Mechanical Impedance and Modal Survey Testing," U.S. Naval Res. Lab., Shock Vib. Bull., No. 42, Pt. 1 (Jan 1972).
32. Schock, R.W., "Prediction of Force Spectra by Mechanical Impedance and Acoustic Mobility Measurement Techniques," U.S. Naval Res. Lab., Shock Vib. Bull., No. 42, Pt. 1 (Jan 1972).

33. Klosterman, A.L. and Lemon, J.R., "Dynamic Design Analysis Via the Building Approach," U.S. Naval Res. Lab., Shock Vib. Bull., No. 42, Pt. 1 (Jan 1972).
34. Ewins, D.J. and Sainsbury, M.G., "Mobility Measurements for the Vibration Analysis of Connected Structures," U.S. Naval Res. Lab., Shock Vib., Bull., No. 42, Pt. 1 (Jan 1972).
35. Hixson, E.L., "Mechanical Impedance and Mobility," Shock and Vibration Handbook, Vol. 1, Chap. 10, McGraw-Hill (1961).
44. Coale, C.W. and Loden, W.A., "The Role of Component Modal Techniques in Dynamic Analysis of Engineering Structures," From NTIS Report AD-740-547 (AFFDL-TR-71-79) Computer Oriented Analysis of Shell Structures, pp 1032-1061 (1971).
45. Thomson, W.T. and Fernandez-Sainz, L., "Spurious Results of the Component Mode Synthesis," Computer and Struc., 3, pp 639-653 (1973).

Transfer Matrix Approach

36. Bahar, L.Y. and Ebner, A.M., "Transfer Matrix Approach to Earthquake Amplification Through Layered Soils," Nucl. Engr. Des., 35, pp 59-67 (1975).
37. Bahar, L.Y., "A Transfer Matrix Approach to Elastodynamics of Layered Media," J. Acoust. Soc. Amer., 57 (3) (1975).
38. Myklestad, N.O., "A New Method of Calculating Natural Modes of Uncoupled Bending Vibration of Airplane Wings and Other Types of Beams," J. Aeronaut. Sci. (Apr 1944).
39. Prohl, M.A., "A General Method for Calculating Critical Speeds of Flexible Rotors," J. Appl. Mech., Trans. ASME, 12 (Sept 1945).
40. Lund, J.W., "Rotor-Bearing Dynamics Design Technology Part V: Computer Program Manual for Rotor Response and Stability," Tech. Rep. AFAPL-TR-65-45, Part V (May 1965).
41. Lund, J.W., "Stability and Damped Critical Speeds of a Flexible Rotor in Fluid-Film Bearings," ASME Paper No. 73-DET-103 (1973).
42. Pestel, E.C. and Leckie, F.A., Matrix Methods in Elastomechanics, McGraw-Hill (1963).
46. Berman, A., "Vibration Analysis of Structural Systems using Virtual Substructures," U.S. Naval Res. Lab., Shock Vib. Bull., No. 43, Pt. 2 (June 1973).
47. Guyan, R.J., "Reduction of Stiffness and Mass Matrices," AIAA J., 3 (2) (1965).
48. Henshell, R.D. and Ong, J.H., "Automatic Masters for Eigenvalue Economization," Intl. J. Earthquake Engr. Struc. Dyn., 3, pp 375-383 (1975).
49. Gallagher, R.H., Finite Element Analysis Fundamentals, Prentice-Hall (1975).
50. Hurty, W.C. and Rubinstein, M.F., Dynamics of Structures, Prentice-Hall (1964).
51. Rubinstein, M.F., Structural Systems - Statics, Dynamics and Stability, Prentice-Hall (1970).
52. Clough, R. and Penzien, J., Dynamics of Structures, McGraw-Hill (1975).
53. Zienkiewicz, O.C., The Finite Element Method in Engineering Science, McGraw-Hill (1971).

Bond Graphs

Finite Element

43. Hurty, W.C., "Dynamic Analysis of Structural Systems Using Component Modes," AIAA J., 3 (4) (Apr 1965).
54. Paynter, H.M., "Generalizing the Concepts of Power Transport and Energy Ports for System Engineering," ASME Paper No. 58-A-296, presented at 1958 Annual Meeting, New York.
55. Karnopp, D.C. and Rosenberg, R.C., Analysis and Simulation of Multiport Systems, The MIT Press (1968).

56. Karnopp, D.C. and Rosenberg, R.C., System Dynamics: A Unified Approach, John Wiley and Sons (1975).
57. Rosenberg, R.C., A User's Guide to ENPORT-4, John Wiley and Sons (1974).
58. Karnopp, D.C., "Computer Representation of Continuous Vibratory Systems Using Normal Modes and Bond Graph Techniques," Simulation (Mar 1968).
59. Karnopp, D.C., "Application of Bond Graph Techniques to Vehicle Dynamics," ASME Paper No. 70-DE-16 (1970).
60. Karnopp, D.C., "Bond Graphs Method in Structural Dynamics," SAE Paper No. 710781, Pres. at Natl. Aeron. and Space Engr. and Manu. Mtg., Los Angeles, September 28-30, 1971.
61. Rosenberg, R.C., "State-Space Formulation for Bond Graph Models of Multiport Systems," J. Dyn. Syst., Meas., and Control, Trans. ASME, 93 (1), Ser. G, pp 35-40 (Mar 1971).
62. Special Issue on Bond Graph Modeling for Engineering Systems, J. Dyn. Syst., Meas., and Control, Trans. ASME, 94 (3), Ser. G (Sept 1972).
63. Dransfield, P., "Power Bond Graphs - Powerful New Tool for Hydraulic System Design," Mach. Des. (Oct 1975).
64. Rosenberg, R.C., "The Bond Graph as a Unified Data Base for Engineering System Design," ASME Paper No. 75-DET-85 (1975).

SHOCK AND VIBRATION INSTRUMENTATION

Robert Plunkett*

Abstract - This article briefly describes recent developments in instrumentation used to measure shock and vibration.

Instrumentation for measuring shock and vibration is a difficult subject to review. To begin with, there is little published literature in the conventional sense. The information that has been published is usually tutorial, written to stimulate sales, or part of some study. This article describes some of the developments that the author thinks will affect future shock and vibration instrumentation. No attempt is made to cite individual articles that are not related to the trends chosen. For the most part, instruments and systems used to measure shock and vibration are discussed; in addition, an important advance in ultrasonic nondestructive testing is mentioned.

SIGNAL PROCESSING AND SYSTEM IDENTIFICATION

The most significant development in instrumentation during the past five years has involved hard wired, digital microcomputers. The combination of microcomputers and wide range (80 dB) logarithmic amplifiers and efficient analog to digital (A to D) converters is on the verge of driving analog filters and data storage systems off the market. Even though most publications pertaining to these computers have a sales emphasis and appear in trade journals, they are well written and contain the technical information necessary for understanding the principles and limitations involved. Wilson [1] discusses digital storage for oscilloscopic display of transient signals; Ramsay [2] shows how this data storage furnished input for further computer processing. Usher [3] describes the general problem of signal conditioning for digital use. The most important digital development for the vibration engineer has been the Fast Fourier Transform (FFT). Lang [4] discusses its role in impact analysis; Potter [5] shows how FFT can be used for structural analysis. These five articles—written by engineers working for equipment manufacturers—do not adequately discuss limitations.

Some limitations are inherent to the measuring technique [6-8]; others have to do with the instrument itself [9, 10]. Digital methods can also be used to control vibration testing [11, 12].

Roberts and Charlton [13] and Lowry [14] show how commercially available equipment can be used to obtain analog rather than digital correlations. The interpretation [15] and storage [16] of analog data are still of interest. Modal excitation of real damped structures requires careful attention to amplitude ratios and phasing of multiple shakers. The problem of shakers has been discussed many times since Fraeijis de Veubeke's original paper in 1946 and is still of concern [17]. There is also interest in environmental vibration testing [18, 19].

The determination of system parameters from measured information [20, 21] furnishes the input necessary for digital analysis of dynamic response. Such analysis is particularly important in helicopter dynamics; the U.S. Army Laboratories have sponsored a substantial study project the results of which have been summarized [22].

INSTRUMENTATION

A survey of currently available accelerometers and vibration exciters has recently been issued [23]. The Australian National Standards Laboratory has made a study of calibration techniques [24-26]. Kenner [27] shows that impact force is accurately measured by a crystal transducer even if the load is not uniformly distributed. New methods that have been proposed for measuring impact [28], flexure [29], angular velocity [30], and acceleration [31] may prove useful for specialized applications. A complicated optical method [32] does not load light structures. A guide to the selection of vibration test equipment is available [33]. Inertial excitation [34] is useful for finding the dynamic response of buildings, nuclear reactors, and other large heavy structures.

*Professor, Aeronautics and Engineering Mechanics, Univ. of Minnesota, Minneapolis, MN 55455

Optical holography is widely used in machinery diagnosis [35-37] and is measuring mode shapes of plates [38-41], cylinders [42], cylindrical shells [43, 44], and rotating propellor blades [45]. Optical holography can also be used to measure shock waves in rotating machinery [46, 47]. Another optical method uses moiré fringes [48-51]. Dynamic photoelasticity is particularly useful for wave propagation studies [51-54].

MATERIAL PROPERTIES

Instrumentation for determining the dynamic properties of materials is a difficult problem. The torsion pendulum is the traditional system [55-57] and is still useful for low frequencies. Intermediate frequency measurements (1 to 1,000 Hz) can be made directly [58, 59], in flexure [60, 61], or on a shaker [20]. Pulse techniques can be used at higher frequencies [62, 63]. The split Hopkinson bar is a useful technique for measuring the dynamic stress strain curve at strain rates from 10^2 to 10^6 per second [64-66].

Acoustic holography is a recent technique developed for ultrasonic nondestructive testing. A textbook has been published [67] as well as a bibliography of federally funded research [68]. Acoustic holography is particularly useful for checking lack of bond [69] and flaws in welds and thick-walled pressure vessels [70].

DIAGNOSTICS

Vibration monitoring has long been used to detect unbalance or bearing wear. About ten years ago, the analog spectrum analyzer made spectral monitoring useful as Mechanical Signature Analysis [71, 72]. It is still being studied [73-77]; digital correlation techniques should make it even more sensitive for detecting wear and mechanical deterioration. More papers on systems used in specific industries would be useful [80]. Methods for finding mode shapes and frequencies [81, 82] and dynamic response of nuclear power plants [83, 84] are in widespread use. New plants are being equipped with instruments to determine the effects of earthquakes [85, 86]. Shock and vibration engineers, along with everyone

else, must pay increasing attention to cost-effectiveness; I have found only one report of a study of cost-optimization of vibration instrumentation [87].

CODA

Many of the topics mentioned above should be reviewed; certainly dynamic photoelasticity, moiré techniques, digital spectral analysis, acoustic holography, and dynamic properties of material should be reviewed. Current practice in determining dynamic system parameters from measured information should also be reviewed. Transducers used in vibration and shock instrumentation are based on the same principles as those used ten years ago. The problems remain about the same. Although design and material improvements have been made, the major advance has been in electronics, high gain operational amplifiers, integrated circuits, wide range logarithmic amplifiers, and hard wired FFD digital minicomputers. The end of the digital computer revolution is not yet in sight; small, inexpensive computers will certainly continue to influence vibration measurement techniques.

REFERENCES

1. Wilson, J., "Transient Capture and Display Techniques," S/V, Sound Vib., 9 (4), p 16 (1975).
2. Ramsay, K.A., "Effective Measurements for Structural Dynamics Testing," S/V, Sound Vib., Pt. I, 9 (11), pp 24-35 (1975); Pt. II, 10 (11), pp 18-31 (1976).
3. Usher, T., Jr., "A Survey of Present Generation Shock and Vibration Signal Conditioners," Proc. Inst. Environ. Sci., 20th Annual Mtg., Washington, D.C., pp 421-429 (1974).
4. Lang, G.F., "Understanding Vibration Measurements," S/V, Sound Vib., 10 (3), pp 26-37 (1976).
5. Potter, R., "Fourier Analysis of Large Structures," S/V, Sound Vib., 9 (4), pp 12-14 (Apr 1975).

Optical holography is widely used in machinery diagnosis [35-37] and is measuring mode shapes of plates [38-41], cylinders [42], cylindrical shells [43, 44], and rotating propellor blades [45]. Optical holography can also be used to measure shock waves in rotating machinery [46, 47]. Another optical method uses moiré fringes [48-51]. Dynamic photoelasticity is particularly useful for wave propagation studies [51-54].

MATERIAL PROPERTIES

Instrumentation for determining the dynamic properties of materials is a difficult problem. The torsion pendulum is the traditional system [55-57] and is still useful for low frequencies. Intermediate frequency measurements (1 to 1,000 Hz) can be made directly [58, 59], in flexure [60, 61], or on a shaker [20]. Pulse techniques can be used at higher frequencies [62, 63]. The split Hopkinson bar is a useful technique for measuring the dynamic stress strain curve at strain rates from 10^2 to 10^4 per second [64-66].

Acoustic holography is a recent technique developed for ultrasonic nondestructive testing. A textbook has been published [67] as well as a bibliography of federally funded research [68]. Acoustic holography is particularly useful for checking lack of bond [69] and flaws in welds and thick-walled pressure vessels [70].

DIAGNOSTICS

Vibration monitoring has long been used to detect unbalance or bearing wear. About ten years ago, the analog spectrum analyzer made spectral monitoring useful as Mechanical Signature Analysis [71, 72]. It is still being studied [73-77]; digital correlation techniques should make it even more sensitive for detecting wear and mechanical deterioration. More papers on systems used in specific industries would be useful [80]. Methods for finding mode shapes and frequencies [81, 82] and dynamic response of nuclear power plants [83, 84] are in widespread use. New plants are being equipped with instruments to determine the effects of earthquakes [85, 86]. Shock and vibration engineers, along with everyone

else, must pay increasing attention to cost-effectiveness; I have found only one report of a study of cost-optimization of vibration instrumentation [87].

CODA

Many of the topics mentioned above should be reviewed; certainly dynamic photoelasticity, moiré techniques, digital spectral analysis, acoustic holography, and dynamic properties of material should be reviewed. Current practice in determining dynamic system parameters from measured information should also be reviewed. Transducers used in vibration and shock instrumentation are based on the same principles as those used ten years ago. The problems remain about the same. Although design and material improvements have been made, the major advance has been in electronics, high gain operational amplifiers, integrated circuits, wide range logarithmic amplifiers, and hard wired FFD digital minicomputers. The end of the digital computer revolution is not yet in sight; small, inexpensive computers will certainly continue to influence vibration measurement techniques.

REFERENCES

1. Wilson, J., "Transient Capture and Display Techniques," S/V, Sound Vib., 9 (4), p 16 (1975).
2. Ramsay, K.A., "Effective Measurements for Structural Dynamics Testing," S/V, Sound Vib., Pt. I, 9 (11), pp 24-35 (1975); Pt. II, 10 (11), pp 18-31 (1976).
3. Usher, T., Jr., "A Survey of Present Generation Shock and Vibration Signal Conditioners," Proc. Inst. Environ. Sci., 20th Annual Mtg., Washington, D.C., pp 421-429 (1974).
4. Lang, G.F., "Understanding Vibration Measurements," S/V, Sound Vib., 10 (3), pp 26-37 (1976).
5. Potter, R., "Fourier Analysis of Large Structures," S/V, Sound Vib., 9 (4), pp 12-14 (Apr 1975).

6. Trifunac, M.D., "Comparisons between Ambient and Forced Vibration Experiments," *Intl. J. Earthquake Engr. Struc. Dyn.*, 1 (2), pp 133-150 (Oct/Dec 1972).
7. Bhat, W.V. and Wilby, J.F., "An Evaluation of Random Analysis Methods for the Determination of Panel Damping," NASA-CR-114423 (Feb 1972).
8. Ni, C-C., "On the Theory and Practice of Structural Resonance Testing," U.S. Naval Res. Lab., Shock Vib. Bull., No. 43, Pt. 4, pp 47-59 (June 1973).
9. Marples, V., "Inherent Limitations in Digital Incremental Oscillator-Analyzer Systems for Mechanical Vibration Testing," *J. Sound Vib.*, 25 (1), pp 157-162 (Nov 1972).
10. Holmes, P.J. and White, R.G., "Data Analysis Criteria and Instrumentation Requirements for the Transient Measurement of Mechanical Impedance," *J. Sound Vib.*, 25 (2), pp 217-243 (Nov 1972).
11. Kim, B.K., "Digitally Controlled Transient Waveform Testing - Alternate Method to Slow Sine Sweep," U.S. Naval Res. Lab., Shock Vib. Bull., 44 (3), pp 1-5 (Aug 1974).
12. Moseley, P., "Digital Analysis and Control in the Vibration Laboratory," Seminar on Understanding Digital Control and Analysis in Vibration Test Systems, Pt. 1, SVIC, Naval Res. Lab., Washington, D.C., pp 79-90 (May 1975).
13. Roberts, A.W. and Charlton, W.H., "Natural Responses of Mechanical Systems Using Correlation Techniques," *Exptl. Mech.*, 15 (1), pp 17-22 (1975).
14. Lowrey, M.J., "Use of Correlation Techniques in Vibration Studies of Plate Systems," *Exptl. Mech.*, 15 (12), pp 476-481 (1975).
15. Ray, J.D. and Bert, C.W., "The Use of Lissajous Figures in Vibration Testing," U.S. Naval Res. Lab., Shock Vib. Bull., 44 (5), pp 117-127 (Aug 1974).
16. Saint-Hilaire, G., Guay, J.M., and Dimoff, K., "Recording Techniques for High Speed Shock Wave Passage Monitored by a Multisensor Array," *J. Phys. E(Sci. Instr.)*, 8 (4), pp 277-280 (Apr 1975).
17. Craig, R.R. and Su, Y-W. T., "On Multiple-Shaker Resonance Testing," AIAA/ASME/SAE 14th Structures, Struc. Dyn., and Matl. Conf., AIAA Paper No. 73-402 (Mar 1973).
18. Salter, J.P. and Roskilly, I.G., "The Resonance-Envelope Random Vibration Test," Royal Armament Res. and Dev. Establishment, Trials and Environmental Testing Dept., Fort Halstead, Engl., RARDE-Memo-18/72, DRIC-BR-29757 (June 1972).
19. Salter, J.P. and Roskilly, I.G., "The Resonance-Envelope Random Vibration Test," Royal Armament Res. and Dev. Establishment, Trials and Environmental Testing Dept., Fort Halstead, Engl., RARDE-Memo-18/72 (June 1972).
20. Pilkey, W.D. ed., "System Identification of Vibrating Structures: Mathematical Models from Test Data," ASME (1972).
21. Ibrahim, S.R. and Mikulcik, E.C., "A Time Domain Modal Vibration Test Technique," U.S. Naval Res. Lab., Shock Vib. Bull., No. 43, Pt. 4, pp 21-37 (July 1973).
22. Berman, A., "Determining Structural Parameters from Dynamic Testing," *Shock Vib. Digest*, 7 (1), pp 10-17 (1975).
23. Magrab, E.B., ed., "Vibration Testing - Instrumentation and Data Analysis," AMD, 12, ASME (1975).
24. Macinante, J.A., "Recent Developments in Accelerometer Calibration," Proc. Noise, Shock and Vib. Conf., Monash Univ., Melbourne, Australia, pp 381-392 (May 1974).
25. Macinante, J.A., Clark, N.H., and Cresswell, B.H., "A Resonance Type Back-to-back Calibrator for Accelerometers," U.S. Naval Res. Lab., Shock Vib. Bull., 44 (4), pp 123-130 (Aug 1974).

26. Macinante, J.A., Clark, N.H., and Cresswell, B.H., "A New Transverse Calibrator for Accelerometers," U.S. Naval Res. Lab., Shock Vib. Bull., 44 (4), pp 131-138 (Aug 1974).
27. Kenner, V.H., "On the Use of Quartz Crystals in Dynamic Stress and Force Transducers," Exptl. Mech., 15 (3), pp 102-106 (Mar 1975).
28. Lyon, R.L. and Zable, J.L., "Impact-Force Source and Impact-Force Calibrator," Exptl. Mech., 13 (6), pp 257-264 (June 1973).
29. Okubo, S., and Monaco, S., "The Flexural Rigidity Sensor: Applications in Non-Destructive Testing," Frank J. Seiler Res. Lab., U.S. Air Force Academy, Colo. Rept. No. FJSRL-TR-75-0017 (Oct 1975).
30. Dubrovin, G.N., Krasilnikov, B.P., and Morzhakov, S.P., "Angular Velocity Vibrometer," Foreign Tech. Div., FTD-HT-23-21113-71 (June 1972), Edited trans. of Patent (USSR) 250 475 p1-2 1970 by Rene E. Courvelle.
31. Macdonald, W.R. and Cole, P.W., "A Seismic Angular Vibration Transducer Employing a Gas Rotor," Royal Aircraft Establishment, Rept. No. RAE-TM-IR-128, Farnborough, Engl. (Apr 1972).
32. Ben-Yosef, N., Ginio, O., and Weitz, A., "Measurement and Analysis of Mechanical Vibration by Means of Optical Heterodyning Techniques," J. Phys. E (Sci. Instr.), 7 (3), pp 218-219 (Mar 1974).
33. "Guide to Selecting Vibration Test Equipment," Instr. Control Syst., 45 (10), pp 67-71 (Oct 1972).
34. Russell, R.H., "New Excitation Sources Simplify Dynamic Testing of Large Structures," S/V, Sound Vib., 8 (10), pp 4-10 (Oct 1974).
35. Hockley, B.S., "Measurement of Vibration by Holography," Inst. Marine Engr., Trans., 84 (6), pp 168-175 (1972).
36. Felske, A. and Happe, A., "Vibration Studies of Bodies and Units Using Holographic Interferometry," Automobiltech. Z., 75 (3), pp 96-102 (Mar 1973).
37. Hazell, C.R., "Holography in Turbomechanical Vibration Problems," Proc. 3rd Turbomech. Seminar, Toronto, Can. (Sept 1974).
38. Evensen, D.A., Aprahamian, R., and Overoye, K.R., "Pulsed Differential Holographic Measurements of Vibration Modes of High Temperature Panels," TRW Systems Group, Redondo Beach, CA, NASA-CR-2028, AM-71-7 (June 1972).
39. Watson, E.E., "Holographic Sound Detection of a Rectangular Plate with a Mass Loading," J. Sound Vib., 36 (4), pp 439-441 (Oct 1974).
40. Croteau, R.E., "A Holographic and Acoustical Investigation of a Plate Vibrating under Water," Rept. No. NUSC-TR-4447 (Oct 1972).
41. Hazell, C.R. and Liem, S.D., "Vibration Analysis of Plates by Real-Time Stroboscopic Holography," Exptl. Mech., 13 (8), pp 339-344 (Aug 1973).
42. Tuschak, P.A. and Allaire, R.A., "Axisymmetric Vibrations of a Cylindrical Resonator Measured by Holographic Interferometry," Exptl. Mech., 15 (3), pp 81-88 (Mar 1975).
43. Liem, S.D., Hazell, C.R., and Blasko, J.A., "Vibration Analysis of Circular Cylinders by Holographic Interferometry," J. Sound Vib., 29 (4), pp 475-481 (Aug 1973).
44. Evensen, D.A., Aprahamian, R., and Jacoby, J.L., "Holographic Measurement of Wave Propagation in Axisymmetric Shells," TRW Systems Group, Redondo Beach, CA., NASA-CR-2063, AM-71-8 (June 1972).
45. Sikora, J.P. and Mendenhall, F.T., "Holographic Vibration Study of a Rotating Propellor Blade," Exptl. Mech., 14 (6), pp 230-232 (1974).

46. Arnoldi, R.A., "Holographic Visualization of Compressor Blade Wake Interaction," Pratt and Whitney Aircraft, Rept. No. PWA-4925 (Mar 1974).
47. Benser, W.A., Bailey, E.E., and Gelder, T.F., "Holographic Studies of Shock Waves within Transonic Fan Rotors," J. Engr. Power, Trans. ASME, 97 (1), pp 75-84 (Jan 1975).
48. Theocrais, P.S., Moiré Fringes in Strain Analysis, Pergamon Press (1969).
49. Beynet, P. and Plunkett, R., "Plate Impact and Plastic Deformation by Projectiles," Exptl. Mech., 11 (2) (1971).
50. Chiang, F.P. and Jaisingh, G., "Dynamic Moiré Methods for the Bending of Plates," Exptl. Mech., 13 (4), pp 168-171 (Apr 1973).
51. Daniel, I.M. and Rowlands, R.E., "On Wave and Fracture Propagation in Rock Media," Exptl. Mech., 15 (12), pp 449-457 (1975).
52. Flynn, P.D., "Dual-Beam Polariscopes and Framing Camera for Dynamic Photoelasticity," Exptl. Mech., 13 (4), pp 178-184 (Apr 1973).
53. Kobayashi, A.S. and Chan, C.F., "A Dynamic Photoelastic Analysis of Dynamic Tear Test Specimens," Exptl. Mech., 16 (5), pp 176-181 (1976).
54. Hermann, J.H., Achenbach, J.D., and Fang, S.J., "A Dynamic Photoelastic Study of Stress-Wave Propagation through an Inclusion," Exptl. Mech., 16 (8), pp 291-299 (1976).
55. Adams, R.D. and Lloyd, D.H., "Apparatus for Measuring the Torsional Modulus and Damping of Single Carbon Fibres," J. Phys. E(Sci. Instr.), 8 (6), pp 475-480 (June 1975).
56. Bleasdale, P.A. and Bacon, D.J., "A Versatile System for the Measurement of Internal Friction in a Torsion Pendulum," J. Phys. E(Sci. Instr.), 8 (6), pp 467-468 (June 1975).
57. Ezell, R.D., "A Torsional Pendulum for Dynamic Mechanical Properties of Polymers," Naval Ordnance Lab., White Oak, MD, Rept. No. NOLTR-73-183 (Nov 1973).
58. Hammant, B.L., "A Forced Vibration Method for the Measurement of Dynamic Mechanical Properties of Materials," Explosives R&D Establishment, Waltham Abbey, Engl., Rept. No. ERDE-TR-130 (Feb 1973).
59. Eldridge, D.A.G. and Mansell, D.H.L., "A Frequency Response Analysis System for the Measurement of the Dynamic Mechanical Properties of Nonmetallic Materials," Explosives R&D Establishment, Waltham Abbey, Engl., Rept. No. ERDE-TR-129 DRIC-BR-36666 (Mar 1973).
60. Papadakis, E.P., "Balanced Resonator for Infra-sonic Measurements of Young's Modulus and Damping in Flexure," J. Test. Eval., 1 (2), pp 126-132 (Mar 1973).
61. Sridharan, P. and Plunkett, R., "Equipment for Measuring Complex Moduli of Thin Coatings at Elevated Temperatures," Trans. ASME, 96 (B3), pp 969-975 (1974).
62. Tennyson, R.C., Zimcik, D., and Tulk, J.D., "The Analysis of the Dynamic Response of Linear Viscoelastic Materials," Toronto Univ., Inst. Aerosp. Studies, UTIAS-159 (Jan 1972).
63. Chiang, T., Tessarzik, J.M., and Badgley, R.H., "Development of Procedures for Calculating Stiffness and Damping Properties of Elastomers in Engineering Applications--Part 1: Verification of Basic Methods," NASA-CR-120965.
64. Nicholas, T., "Instrumental Impact Testing Using a Hopkinson Bar Apparatus," Air Force Materials Lab., Wright-Patterson AFB, Ohio, Rept. No. AFML-TR-75-54 (July 1975).
65. Christensen, R.J., Swanson, S.R., and Brown, W.S., "Split Hopkinson Bar Tests on Rock under Confining Pressure," Exptl. Mech., 12 (11), pp 508-513 (Nov 1972).

66. Bertholf, L.D. and Karnes, C.H., "Two-dimensional Analysis of the Split Hopkinson Pressure Bar System," *J. Mech. Phys. Solids*, 23 (1), pp 1-19 (Feb 1975).
67. Hildebrand, B.P. and Brendan, B.B., An Introduction to Acoustical Holography, Plenum (1972).
68. Craig, D.M. and Lehman, E.J., Bibliography of Acoustic Holography, NTIC (May 1975).
69. Barbarisi, M.J. and Chisholm, B.R., "Initial Feasibility Study Employing Holographic Vibrational Analysis to Locate Nonbonds in Thick Ceramic to Fiberglass Composite," Picatinny Arsenal, Dover, N.J., Rept. No. PA-TR-4675 (Sept 1974).
70. Hildebrand, B. and Collins, D., "Evaluation of Acoustical Holography for the Inspection of Pressure Vessel Sections," *Matl. Res. Stds.*, ASTM, 12 (12), pp 23-31 (Dec 1972).
71. Lavoie, F.J., "Signature Analysis: Product Early Warning System," *Mach. Des.*, pp 149-160 (Jan 1969).
72. Bannister, R.L. and Donato, V., "Signature Analysis of Turbomachinery," *S/V, Sound Vib.*, 5 (9), pp 14-21 (1971).
73. Babrin, A.S. and Anderson, J.J., "Mechanical Signature Analysis," *S/V, Sound Vib.*, 7 (4), pp 35-42 (1973).
74. Babkin, A.S. and Anderson, J.J., "Mechanical Signature Analysis of Ball Bearings by Real Time Spectrum Analysis," *J. Environ. Sci.*, 16 (1), pp 9-17 (Jan/Feb 1973).
75. Randall, R.B., "Vibration Signature Analysis-Techniques and Instrument Systems," *Proc. Noise, Shock and Vib. Conf.*, Monash Univ., Melbourne, Australia, pp 445-455 (May 1974).
76. Shea, J.M. and Catlin, J.B., "Establishing Machinery Condition at Startup through Vibration "Base-line" Analysis," ASME Paper No. 72-PET-13 (1972).
77. Carmody, T., "The Measurement of Vibration as a Diagnostic Tool," *Inst. Marine Engr. Trans.*, 84 (6), pp 147-159 (1972).
78. Howard, P.L., "Application of Shock Pulse Technology and Vibration Analysis to Rolling Bearing Condition Monitoring," *Proc. 20th Intl. Instrum. Symp.*, Albuquerque, NM, pp 231-238 (May 1974).
79. Harris, R.W., "The Measurement of Mechanical Integrity in a Reactor Fuel Element by the Analysis of External Vibration Signals," *Nucl. Engr. Des.*, 23 (2), pp 182-186 (Nov 1972).
80. Maddox, V., "Vibration Monitoring and Diagnostic Instrumentation for Industrial and Marine Gas Turbines," ASME Paper No. 73-GT-50 (1973).
81. Baťa, M. and Plachý, V., "Some Notes on the Experimental Analysis of the Vibrations of Machine Foundations," *Polytech. Inst. Bucharest, Romania, 44th Euromech. Colloq.*, Dynamics of Machine Foundations, pp 275-289 (Oct 1973).
82. Smith, C.B., "Dynamic Testing of Full-scale Nuclear Power Plant Structures and Equipment," *Nucl. Engr. Des.*, 27 (2), pp 199-208 (May 1974).
83. Ibañez, P., Matthiesen, R.B., Miller, W.R., and Smith, C.B., "Experimental Vibration Tests at Nuclear Power Plants," *Trans. Instr. Soc. Amer.*, 11 (3), pp 286-296 (1972).
84. Kao, G.C., "Testing Techniques for Simulating Earthquake Motion," *J. Environ. Sci.*, XVIII (2), (Mar/Apr 1975).
85. Pauly, S.E., "Earthquake Instrumentation for Nuclear Facilities," *Nucl. Engr. Des.*, 27 (3), pp 359-371 (July 1974).
86. Morcos, A. and Chu, S.-L., "Seismic Instrumentation for Nuclear Plants," *ASCE J. Power Div.*, 99 (PO2), pp 281-285 (Nov 1973).
87. Young, J.P., "Spacecraft Vibration Test Level Cost Optimization Study," *U.S. Naval Res. Lab., Shock Vib. Bull.*, 44 (5), pp 99-105 (Aug 1974).

ANNUAL ARTICLE INDEX

FEATURE ARTICLES

	ISSUE	PAGES
Eshleman, R.L. and Pusey, H. Progress in Shock and Vibration Standards During 1975	1	5-23
Leipholz, H. Use of Galerkin's Method for Vibration Problems	2	3-18
Pope, L.D. Low-Wave Number Constant of Turbulent Boundary Layer Pressure Fluctuations	3	3-10
Holzer, S. Dynamic Stability of Elastic Imperfection - Sensitive Shells	4	3-10
Klosner, J.M. Response of Shells to Acoustic Shocks	5	3-13
Nakra, B.C. Vibration Control with Viscoelastic Materials	6	3-12
Macinante, J.A. Vibration Isolating Mountings for Sensitive Equipment - New Design Criteria	7	3-24
Olhoff, N. A Survey of the Optimal Design of Vibrating Structural Elements Part I: Theory	8	3-10
Olhoff, N. A Survey of the Optimal Design of Vibrating Structural Elements Part II: Applications	9	3-10
Jones, D.I.G. High Temperature Damping of Dynamic Systems	10	3-16
Smith, C.B. Seismic and Operational Vibration Problems in Nuclear Power Plants	11	3-13
Dawson, B. Vibration Condition Monitoring Techniques for Rotating Machinery	12	3-8

LITERATURE REVIEWS

	ISSUE	PAGES
Mayne, R. Optimization Techniques for Shock and Vibration Isolator Development	1	87-94
Elishakoff, I. Bolotin's Dynamic Edge Effect Method	1	95-104
Rades, M. Methods for the Analysis of Structural Frequency - Response Measurement Data	2	73-88
Iwatsuba, T. Vibration of Rotors through Critical Speeds	2	89-98
Huang, T. Vibration of Bridges	3	61-76
Hobaica, E.C. and Sweet, G. Behavior of Elastomeric Materials under Dynamic Loads	3	77-88
Huseyin, K. Vibration and Stability of Mechanical Systems	4	56-66
Johns, D.J. Wind-Excited Behavior of Structures	4	67-75
Chatelin, F. Approximate Methods for Computing the Eigenelements of Integral and Differential Linear Operators	5	15-19
Soong, T.T. and Cozzarelli, F.A. Vibration of Disordered Structural Systems	5	21-35
Lee, T.H. Soil-Structure Interaction - Nuclear Reactors. The Continuum Approach	6	15-23
de Silva, B.M.E., Green, D.R., and Grant, G.N.C. Two Point Boundary Value Problems in the Optimal Control Design of Turbine Blades	6	25-33
Dym, C.L. Variational Methods of Analysis	7	27-31
Mulcahy, T.M. and Wambsganss, M.W. Flow-Induced Vibration of Nuclear Reactor System Components	7	33-45

LITERATURE REVIEWS, Continued

	ISSUE	PAGES
Gladwell, G.M.L. The Vibration of Cylinders	8	13-34
Engin, A.E. On the Large-Deformation Theory of Fluid-Filled Shells of Revolution	8	35-47
Ungar, E.E. Prediction and Control of Vibration in Buildings	9	13-24
GangaRao, H.V.S. Vibration Analysis of Grid-Works	9	25-30
Willis, T. Nonlinear Analysis of Rail Vehicle Dynamics	10	19-35
Bert, C.W. Damping of Composite and Sandwich Panels. Part I.	10	37-48
Bert, C.W. Damping of Composite and Sandwich Panels. Part II.	11	15-24
Hannibal, A.J. Modeling of Vibrating Systems - An Overview. Part I. Force Balance and Energy Methods	11	25-29
Hannibal, A.J. Modeling of Vibrating Systems - An Overview. Part II. Approximate Methods, Mechanical Impedance and Mobility, Transfer Matrix Method, Finite Element Methods, and Bond Graphs	12	11-20
Plunkett, R. Shock and Vibration Instrumentation	12	21-26

BOOK REVIEWS

VIBRATION AND NOISE IN MOTOR VEHICLES

Published by the Institution of Mechanical Engineers, 1972

This volume contains the 17 papers and discussions of a 1971 symposium arranged by the Automobile Division of the Institution of Mechanical Engineers (IME) and the Advanced School of Automotive Studies.

The book reflects the usual high standards of the IME. The contents should be of interest to researchers, engineering practitioners, and students particularly motor vehicle vibration analysts and acousticians. Most of the papers were presented by either academicians (or researchers) and industrial practitioners. The papers comprise research findings and tutorial expositions. The latter include descriptions of analytical and laboratory methods either in use or under development. The contents cover noise and vibration isolation, vibratory response of mechanical components used in motor vehicles, and the analysis and design of motor vehicle systems so as to reduce levels of vibratory response.

With respect to noise and vibration isolation, Davies and Alfredson demonstrate that a linear acoustic model adequately describes exhaust systems and can be used to design silencers (i.e., mufflers) for internal combustion engines. Bolton-Knight showed, by analysis and experiment, that engine mounting locations and configurations can be so selected as to reduce the noise and vibration levels in the passenger compartment of motor vehicles. Puydak and his associates reviewed the basic principles involved in selecting and using elastomers for dynamic mounting systems; they applied these principles to the engine mount selection problem. Waters discussed the sources and characteristics of commercial vehicle noise and concluded that noise shields reduce environmental engine noise. Jennequin was concerned with noise within the passenger compartment; he concluded that it is feasible to compute the modal response of the enclosed air volume in order to identify the interior panels responsible for inducing the noise. Fontanet outlined methods that have been used to reduce noise generated by second-order reciprocating forces of a four-cylinder, in-line engine.

One vibratory response of motor vehicle components -- the mechanism of "brake squeal" -- was addressed by Spurr, who argued that squeal arises from the coupling of vibrations within the brake assembly. Earles and Soar pointed out that a generally acceptable solution for solving the problem of squeal has not yet been found. Crankshaft vibrations are under considerably better control, however, as was shown by Hodgetts with regard to an internal combustion engine. Sykes and Wyman described the use of receptance methods for calculating the vibratory responses of typical drivelines. The control of noise generated by gears in automotive transmissions was reviewed by Ill. Egbuson et al examined the vibratory behavior of the rear-axle assembly commonly employed in motor cars.

The tendency in the remaining papers was to regard the motor vehicle as a complete system. Barson and Dodd presented experimental results of tires on irregular surfaces. Mills and Dunn, who were concerned primarily with the tire as an isolation element between vibration source and occupant, measured the mechanical impedance/mobility of a variety of tires and showed that resonant frequencies and mode shapes vary with tire design. Phillips also considered the transmissibility of road noise. Instrumentation and test techniques for solving noise, vibration, and harshness problems were described by Timms and O'Brien from the standpoint of the development process facing the manufacturer. Butkunas stressed the need for relating laboratory results with those obtained on the road. He described two experimental methods that can be used on the road to obtain the vehicle transfer function and averaged instantaneous mode shapes.

L. Segel
Professor of Mechanical Engineering
The University of Michigan
Ann Arbor, Michigan 48109

RELIABILITY DESIGN FOR VIBROACOUSTIC ENVIRONMENTS

Edited by: D.D. Kana and T.G. Butler
ASME Publication AMD - Volume 9 (1974)

In this book reliability is shown to be a statistical parameter. The foreword states: "The purpose of this (volume) is to present some fundamentals and current developments in the application of reliability concepts to the prediction of successful functioning of hardware and structures in vibration and acoustic environments." Reliability has become a valuable tool in equipment design for seismic environments and rotating machinery.

This little volume consists of nine papers. The first, which deals primarily with mechanical reliability theory, contains approaches to the reliability of mechanical components and information about cumulative fatigue reliability. The Goodman diagram, Von Mises's equations of stress, and the normal distribution curve are applied to fatigue loading of materials. The reviewer would have liked a discussion of the application of fatigue under random environmental conditions.

The second paper discusses the unpredictability of materials and the properties and geometry of components and their influence upon performance of the entire system. The authors propose a nine point program for developing design tolerances.

The next two papers describe reliability design in shipbuilding and seismic reliability of equipment design. The latter was shown to be necessary after the 1971 San Fernando Earthquake. The authors suggest design criteria and spectra for testing in a seismic environment and methods for reducing the effect on equipment of high acceleration. An outline for simulating a model of a lifeline system of a large metropolitan area is included.

The fifth paper considers data analysis of random signals, the meaning of power spectral density, coherence function, AD conversion, and transfer function. An example of coherence behavior is given. The author has published an in-depth study entitled "Digital Time Series Analysis."

The sixth paper considers recent developments in vibration equivalence concepts. The application of Miner's rule is stressed and applied to a composite equivalence profile in order to review the design of a product. Each potential damage-producing process and its characteristics are identified. The reviewer was disappointed that random-sine equivalence and its application to design studies were not considered in any detail.

The seventh paper describes accelerated reliability testing of missile components under vibroacoustic environments. Actual missile components were tested in a simulated environment. The statistical evaluation of the breakdown of mechanical and electrical components should serve as an eye opener to those number-conscious designers with little conception of physical reality.

The final papers consider the application of field vibration data in laboratory tests of transported vehicles and in space payload dynamic testing.

The book is a good compendium of reliability testing in vibroacoustic environments. In my opinion information about reliability in the design of bridges and buildings subjected to wind loadings should have been included.

Herb Saunders
General Electric Company
Bldg. 43, Room 319
Schenectady, New York 12345

REVIEWS OF MEETINGS

47TH SHOCK AND VIBRATION SYMPOSIUM

19-21 October 1976
Albuquerque Convention Center
Albuquerque, New Mexico

The 47th Shock and Vibration Symposium, sponsored by the Shock and Vibration Information Center (SVIC), was held in Albuquerque, New Mexico, in October. It was hosted by the Defense Nuclear Agency (DNA), Washington, D.C. and the Field Command Defense Nuclear Agency with the cooperation of the Air Force Weapons Laboratory, Kirtland AFB, New Mexico. The formal technical program contained more than 80 papers (see Vol. 8, No. 9, of the DIGEST for the complete program; paper summaries are available from the SVIC); a session of short reports of work in progress; and panel sessions on dynamic effects on reliability, modal testing and analysis, and survivability and vulnerability of military systems. Henry Pusey, Director of the SVIC, the members of the SVIC staff, and the program committee are to be congratulated for assembling an interesting program. Among the more than 350 participants were representatives of the federal government, industry, and the teaching profession. The attendees participated in both the formal and informal technical programs, thereby effecting a meaningful transfer of shock and vibration technology.

The Opening Session

The opening session was chaired by Dr. Eugene Sevin, Chief of Strategic Structures Division, DNA. Symposium participants were welcomed on behalf of the DNA by General Thomas E. Lacy. Colonel Lawrence Epley greeted the Symposium on behalf of the Air Force, and Mayor Harry Kinney did the same on behalf of the City of Albuquerque. General Lacy described the formation and scope of DNA and noted that, like the SVIC, DNA will soon celebrate its 30th anniversary. Colonel Epley stated the mission of the Air Force Weapons Laboratory in peace time: to prepare to fly and fight. He cited new programs

involving missiles and lasers. Mayor Kinney, a former engineer with Sandia Laboratories, described the growth and rebuilding of Albuquerque.

The keynote speaker, Dr. Hua Lin, is Assistant Director (Offensive Systems), Office Director of Defense Research and Engineering, Washington, D.C.. During his talk on "Shock and Vibration Considerations in Weapon System Acquisition," Dr. Lin discussed weapon systems development, the role of vibrations in repairs for the B1 bomber, and the effect of shock and vibration considerations on the structural integrity and acoustic radiation of submarines. He noted that shock and vibration are often dealt with as necessary evils and that their importance is often recognized only after a program is in trouble. Unnecessarily high costs for corrective measures result. Dr. Lin spoke of the concern of the Department of Defense with successful performance of a mission, the capability to execute the mission at the desired time, and the affordability of the system.

The thrust of the talk was the desirability to avoid the costly pitfalls of weapon systems procurements. These pitfalls include unrealistic shock and vibration specifications, design trade offs (i.e., the exclusion of effective shock and vibration efforts), and difficulty in verifying performance. Unrealistic specifications are the most common problem. Dr. Lin cited unquestioned use of MIL-STD-810B and argued that undue conservatism must be avoided. Determination of realistic specifications requires better prediction techniques: probabilistic approaches would be useful, and early conceptual tests would allow the identification of limits to the problem. In Dr. Lin's opinion, shock and vibration efforts should begin during the design trade-off process, in which reasonable specifications are used to avoid later fix-up costs. In his concluding remarks Dr. Lin again stressed affordability of weapon systems, trade-off studies early in the design process, less conservative design, and reasonable specifications. He stressed the value of the Shock and Vibration Symposium as a forum for personal contact and discussion of technical problems

Three invited speakers were part of the opening session. Major Donald Gage of the Space and Missile Systems Organization discussed blast, shock, and vibration design considerations for Missile X. Major Gage described the character and objective of Missile X - an underground mobile missile - as well as hardening and isolation mounting systems applied to the missile.

Mr. Noah J. Hurst of the Ballistic Missile Systems Defense Command talked about nuclear hardness in a missile defense system for now and for the future. Mr. Thomas Kennedy of DNA gave an excellent review on instrumentation technology - which includes, according to his definition, the entire measurement system. He discussed phenomena measurement, data transmission, recording, data reduction, and reporting. Among the factors which he feels require attention are higher frequency and level measurement capability, increased linearity range, and phase measurements. Mr. Kennedy summarized recent developments: data processing at the transducers, fiber optics for transmission, multiplexing of data, and telemetry. He appeared interested in direct digital recording of data - a feat that will require development of digital transducers.

The Technical Program

The technical program contained the following formal sessions: shock testing and analysis, isolation and damping, vibration testing, vibration analysis, instrumentation and data analysis, systems applications, and structural dynamics. Panel session topics included dynamics effects on reliability and survivability and vulnerability of military systems. A planning session for a seminar on modal testing and analysis was also held. An interesting session on short reports of work in progress included elastomeric mount characterization, impact testing, vibration testing, vibration analysis of shipboard and missile systems, and a computational model for piezoelectric materials in transducers.

The Symposium is the only forum for discussion of shock technology. Many of the papers pertained to the application of analytic and testing techniques to military and industrial problems. New and practical means for seismic and weapon effects testing include waveform reproduction on electrodynamic shakers and hydraulic actuators. Scaling of strong shock Hugoniot and shock spectra and responses using a

pocket calculator were of interest.

Isolation technology used in the SAFEGUARD System and elastomeric element design were part of the session on isolation and damping. A new technological development in damping was described: the characterization of bulk cushion material for its viscoelastic and thermal properties. Reports were also given on the use of damping in the reduction of vibration and stress in aircraft. Testing techniques, fixture design, and new instrumentation were discussed during the vibration testing session. In addition case histories on vibration testing of hardware were given. The vibration analysis session included reports of applications of vibration theory to the solution of cable, plate, panel, and structural problems. A session on structural dynamics contained descriptions of unusual problems on composite-material flywheels for energy storage, pipeline response, and gas dynamic laser mounting forces.

New measurement equipment and techniques were part of the Instrumentation and Data Analysis session. Measurement of angular vibration using conventional accelerometers should prove to be valuable for many engineers. A low power laser and light-sensitive diode for measuring displacement data may eventually have wide application.

A session on systems identification and computer applications was concerned with the application of known techniques to existing problems and with the development of new techniques.

The Symposium papers will be reviewed for the quality of technical content and presentation. Selected papers will be published in the 47th Shock and Vibration Bulletin - available from the Shock and Vibration Information Center, Washington D.C..

The Ladies Program

In conjunction with the Symposium, an extensive ladies program, planned by Mrs. Pusey and Mrs. McWhirter and capably directed by Barbara Reeback of Bienvenidos Tour Gals, was given. More than 25 women renewed acquaintances during a trip to Española and environs for shopping - and a delicious lunch at Rancho de Chimayo; a visit to old Santa Fe, including The Fenn Gallery; and a fascinating tour of the Acoma Pueblo. The Symposium activities concluded with a tour of Sandia Laboratories on Friday morning.

SHORT COURSES

JANUARY

INTRODUCTORY COMPUTER METHODS AND APPLICATIONS

Dates: January 11 - 14, 1977

Place: The University of Texas at Austin

Objective: This four-day course will introduce participants to problem formulation and problem solving in the area of structural dynamics. Emphasis will be placed on mathematical modeling of structures and on numerical methods for solving free vibration and dynamic response problems. Special sessions will treat applications of special interest to aerospace, civil, and mechanical engineers. Participants completing this course should have some knowledge of numerical techniques used in current computer programs having structural dynamics capability.

Contact: Engineering Institutes, College of Engineering, Cockrell Hall 2.102, The University of Texas at Austin, Texas 78712

DIGITAL SIGNAL PROCESSING

Dates: January 18 - 20, 1977

Place: Cincinnati, Ohio

Objective: Theory and applications of Fast Fourier Transform (FFT) hardware will be discussed. The meaning and uses of Fourier transforms, transfer functions, frequency response functions and convolution in the frequency and time domains will be covered. A discussion on architectural and operational concepts of a dual-channel digital signal processor is included in the program. Finally, applications of a dual-channel FFT processor to different engineering and signal analysis problems will be covered.

Contact: Mr. Bob Kiefer, Spectral Dynamics Corp. of San Diego, P.O. Box 671, San Diego, CA 92112
Tele. (714) 565-8211

PREVENTIVE MAINTENANCE AND FAULT DIAGNOSIS

Dates: January 31, February 1 & 2, 1977

Place: University of Houston Hotel

Objective: This seminar is devoted to the understanding and application of vibration technology to machinery preventive maintenance programs and fault diagnosis problems. Basic and advanced techniques with illustrative case histories and demonstrations will be discussed by industrial experts and consultants. Topics to be covered in the seminar include development of preventive maintenance programs; measurements, analysis, and data reduction, shock pulse techniques for bearing analysis; computer monitoring; and acoustic techniques. An instrumentation show will be held in conjunction with this seminar.

Contact: Dr. R. L. Eshleman, Vibration Institute, Suite 206, 101 W. 55th St., Clarendon Hills, IL 60514
Tele. (312) 654-2254/654-2053

FEBRUARY

INTRODUCTION TO VIBRATION AND SHOCK TESTING, MEASUREMENT, ANALYSIS AND CALIBRATION

Dates: February 14 - 18, 1977

Place: Santa Barbara, California

Objective: This course will benefit plant engineers and maintenance personnel responsible for on-line condition analysis of rotating machinery. Electronic techniques for analysis of vibration and sound signatures in terms of specific machinery faults will be discussed. This course will concentrate upon equipments and techniques rather than upon theory.

Contact: Mr. W. Tustin, Tustin Institute of Technology, Inc., 22 E. Los Olivos St., Santa Barbara, CA 93105
Tele. (805) 963-1124

MACHINERY VIBRATION ANALYSIS

Dates: February 15 - 17, 1977

Place: Lanham, Maryland

Objective: This course will cover such areas as fundamentals of vibration, vibration and analysis, transducer concepts, machine protection systems, analyzing vibration to predict failures, reducing unbalance forces, reducing misalignment forces, interpreting vibration signatures, improving analysis capability, and managing vibration data by computer.

Contact: Mr. Bob Kiefer, Spectral Dynamics Corp. of San Diego, P.O. Box 671, San Diego, CA 92112
Tele. (714) 565-8211

MODELING IN ENGINEERING DYNAMICS

Dates: February 28 - March 4, 1977

Place: San Antonio, Texas

Objective: This course is recommended for prospective students who have a bachelor's degree in some field of engineering, physics, or mathematics. The intent of this course is to introduce and illustrate to engineers, physicists, and scientists investigating transient phenomena the powerful tool of model analysis, and although the course is directed toward experienced personnel, a newcomer to the fields of survivability analysis, terminal ballistics effects, safety engineering, engineering dynamics, etc. can keep pace by diligently applying himself.

Contact: Mr. Peter S. Westine, Southwest Research Institute, P.O. Box 28510, San Antonio, TX 78284

MARCH

CORRELATION AND COHERENCE ANALYSIS FOR ACOUSTICS AND VIBRATION PROBLEMS

Dates: March 7 - 11, 1977

Place: UCLA

Objective: This course covers the latest practical techniques of correlation and coherence analysis--ordinary, multiple and partial--for solving acoustics and vibration problems in physical systems.

Contact: Continuing Education in Engineering and Mathematics, Short Courses, 6266 Boelter Hall, UCLA Extension, Los Angeles, CA 90024
Tele. (213) 825-1047

MEASUREMENT SYSTEMS ENGINEERING

Dates: March 14 - 19, 1977

Place: Phoenix, Arizona

Objective: Program emphasis is on how to obtain valid, cost-effective data in the field and in the laboratory during the next decade through increased productivity of data acquisition systems and groups. The latest developments in the new Unified Approach to the Engineering of Measuring Systems to achieve these aims, will be presented.

Contact: Prof. P. Stein, Short Course Director, 5602 East Monte Rosa, Phoenix, AZ 85018
Tele: (602) 945-4603/965-3124

NEWS BRIEFS

news on current
and Future Shock and
Vibration activities and events

ASTM COMMITTEE ON ENVIRONMENTAL ACOUSTICS APPROVES NEW STANDARDS

Two proposed new standards were approved for submission to ASTM letter ballot during the meetings of American Society for Testing and Materials (ASTM) Committee E-33 on Environmental Acoustics in Denver on October 11-13, 1976.

A proposed Method for Laboratory Measurement of the Noise Reduction of Sound Isolating Enclosures describes reverberation room measurement of the noise reduction of audiometric rooms, personnel booths, and other sound isolating enclosures.

A proposed Tentative Recommended Practice for Measuring a Single-Number Rating of the Airborne Sound Isolation in Multifamily Dwellings Suitable for Use in Building Specifications describes uniform procedures for determining the A-weighted noise reduction between neighboring (usually adjacent) rooms in a building. This recommended practice is intended for use by building code writers and others concerned with sound isolation between dwelling units, hotel and motel rooms, hospital rooms, and small offices.

The next meetings of Committee E-33 will be on April 11-13, 1977 in Bethesda, MD. Meeting details can be obtained from the Committee Secretary, Charles W. Rodman, Battelle Memorial Institute, 505 King Ave., Columbus, OH 43201 (Tele: 614-424-6424).

FIFTEENTH MIDWESTERN MECHANICS CONFERENCE

The Fifteenth Midwestern Mechanics Conference will be held March 23 - 25, 1977, at the University of Illinois at Chicago Circle. Members of the mechanics community throughout the United States and Canada are invited to join as participants. Unlike those of previous Midwestern Mechanics Conferences,

the Proceedings of this conference will contain only the abstracts of papers. Full publication elsewhere in professional journals is permitted and encouraged.

For further information, contact Prof. T.C.T. Ting, Dept. of Materials Engineering, Univ. of Illinois at Chicago Circle, Box 4348, Chicago, IL 60680

TWENTY-THIRD INTERNATIONAL INSTRUMENTATION SYMPOSIUM

This will be the fourth in a series of symposia jointly sponsored by the Aerospace Industries and Test Measurement Divisions of the Instrument Society of America. The previous meetings have established this symposium as the outstanding forum for presentation of original work in aerospace and test measurement instrumentation. Papers will be presented which cover advances in, or new applications of, instrumentation devices, systems, or techniques in the following fields:

MEASUREMENTS: Strain; Motion; Flow; Pressure; Thermal; Acoustics, Shock and Vibration

INSTRUMENTATION TECHNIQUES & HARDWARE: NDT & Acoustic Emission; Analog Signal Conditioning; Microprocessors & Minicomputers; Electro-Optic/Photographic

APPLICATIONS: Aircraft; Space & Reentry Vehicles; Oceanography, Land Vehicles; Machinery; Nuclear Reactors; Automation

TEST CONTROL & DATA ANALYSIS: Real Time Display & Control, Microprocessor, Minicomputer and Calculator Applications

The symposium will be held at the Dunes Hotel in Las Vegas, Nevada on May 1 through 5, 1977. For additional information, contact: Mr. Phillip Legendre, Aerospace Corp., 2350 East El Segundo Blvd., El Segundo, CA 90245

ABSTRACT CATEGORIES

ANALYSIS AND DESIGN

Analogs and Analog
 Computation
 Analytical Methods
 Dynamic Programming
 Impedance Methods
 Integral Transforms
 Nonlinear Analysis
 Numerical Analysis
 Optimization Techniques
 Perturbation Methods
 Stability Analysis
 Statistical Methods
 Variational Methods
 Finite Element Modeling
 Modeling
 Digital Simulation
 Parameter Identification
 Design Information
 Design Techniques
 Criteria, Standards, and
 Specifications
 Surveys
 Tutorial
 Mode Synthesis

COMPUTER PROGRAMS

General
 Natural Frequency
 Random Response
 Stability
 Steady State Response
 Transient Response

ENVIRONMENTS

Acoustic
 Periodic
 Random
 Seismic
 Shock
 General Weapon
 Transportation

PHENOMENOLOGY

Composite
 Damping
 Elastic
 Fatigue
 Fluid
 Inelastic
 Soil
 Thermoelastic
 Viscoelastic

EXPERIMENTATION

Balancing
 Data Reduction
 Diagnostics
 Equipment
 Experiment Design
 Facilities
 Instrumentation
 Procedures
 Scaling and Modeling
 Simulators
 Specifications
 Techniques
 Holography

COMPONENTS

Absorbers
 Shafts
 Beams, Strings, Rods
 Bearings
 Blades
 Columns
 Controls
 Cylinders
 Ducts
 Frames
 Gears
 Isolators
 Linkages
 Mechanical
 Membranes, Films, and
 Webs
 Panels

Pipes and Tubes
 Plates and Shells
 Rings
 Springs
 Structural

SYSTEMS

Absorber
 Acoustic Isolation
 Noise Reduction
 Active Isolation
 Aircraft
 Artillery
 Bioengineering
 Bridges
 Building
 Cabinets
 Construction
 Earth
 Electrical
 Foundations
 Helicopters
 Human
 Isolation
 Material Handling
 Mechanical
 Metal Working and Forming
 Off-Road Vehicles
 Optical
 Package
 Pressure Vessels
 Pumps, Turbines, Fans,
 Compressors
 Rail
 Reactors
 Reciprocating Machine
 Road
 Rotors
 Satellite
 Self-Excited
 Ship
 Spacecraft
 Structural
 Transmissions
 Turbomachinery
 Useful Application

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, Va., 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Zeeb Rd., Ann Arbor, MI. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

ANALYSIS AND DESIGN39	PHENOMENOLOGY45	SYSTEMS60
Analytical Methods39	Damping45	Noise Reduction60
Integral Transforms39	Fluid45	Aircraft61
Numerical Analysis39	Soil46	Bioengineering66
Optimization Techniques39	Viscoelastic47	Bridges66
Finite Element Modeling39		Building66
Modeling40	EXPERIMENTATION48	Construction67
Digital Simulation40	Diagnostics48	Helicopters67
Parameter Identification40	Facilities48	Human68
Design Information41	Instrumentation50	Isolation68
Criteria, Standards, and	Simulators50	Material Handling69
Specifications41	Techniques50	Mechanical69
Surveys41		Metal Working and
Tutorial42		Forming69
		Package69
COMPUTER PROGRAMS43	COMPONENTS51	Pumps, Turbines, Fans,
General43	Beams, Strings, Rods51	Compressors70
Natural Frequency43	Bearings53	Rail71
ENVIRONMENTS44	Blades54	Reactors72
Acoustic44	Cylinders55	Reciprocating Machine72
Seismic44	Ducts56	Road72
Shock44	Pipes and Tubes57	Rotors73
Transportation44	Plates and Shells57	Satellite74
	Rings59	Spacecraft74
	Structural59	Structural75
		Turbomachinery76

ANALYSIS AND DESIGN

ANALYTICAL METHODS

(Also see No. 1911)

76-1872

Application of an Extended Hamilton's Principle to Damped Discrete and Continuous Systems

M. Levinson

Dept. of Civil Engrg. and Engrg. Mechanics, McMaster Univ., Hamilton, Ontario, Canada L8S 4L7
Mech. Res. Comm., 3, pp 125-131 (1976) 10 refs
Sponsored by the National Res. Council of Canada

Key Words: Hamiltonian principle, Mechanical systems, Damped structures

This paper shows how an extended Hamilton's principle may be applied to a wide variety of dissipative mechanical systems including damped acoustic waves. Both linear and nonlinear problems may be treated in this manner. The value of the extended Hamilton's principle, motivated by the principle of virtual work, is that it provides a basis upon which Rayleigh-Ritz and variationally based finite element approximations can be made. The principle was originally formulated in order to study (nondissipative) nonconservative problems of elastic stability and it has been used as the basis of finite element studies.

INTEGRAL TRANSFORMS

(See No. 1888)

NUMERICAL ANALYSIS

76-1873

Normalized Frequencies and Deviations as Function of Coupling, Mass-Loading and Harmonic: Numerical Results for Lateral Excitation

A. Ballato

Army Electronics Command, Fort Monmouth, NJ
Rept. No. ECOM-4404, 160 pp (Apr 1976)
Availability: Paper copy available from CDR. U.S. Electronics Command, ATTN: DRSEL-TL-ML, Fort Monmouth, NJ 07703

Key Words: Piezoelectric transducers, Resonant frequency, Vibration frequencies

This report provides specific numerical results, in the form of data tables, obtained from the solution of the pertinent transcendental equations governing the vibration frequencies of mass-loaded piezoelectric plates, in the one-dimensional approximation. The tables refer to excitation of a single thickness plate mode by an electric field in the lateral direction. Resonance and antiresonance frequencies are given in normalized form, along with frequency deviations, as function of harmonic of operation, piezoelectric coupling factor, and amount of mass-loading.

OPTIMIZATION TECHNIQUES

(See No. 1958)

FINITE ELEMENT MODELING

(Also see No. 1990)

76-1874

Three-Dimensional Finite Element Analysis for High Velocity Impact

S.T.K. Chan, C.H. Lee and M.R. Brashears

Lockheed Missiles and Space Co., Res. and Engrg. Ctr., Huntsville, AL, Rept. No. NASA-CR-134933; LMSC-HREC-TR-D390900, 160 pp (Aug 1975)
N76-21592

Key Words: Finite element technique, Impact response

A finite element algorithm for solving unsteady, three-dimensional high velocity impact problems is presented. A computer program was developed based on the Eulerian hydroelasto-viscoplastic formulation and the utilization of the theorem of weak solutions. The equations solved consist of conservation of mass, momentum, and energy, equation of state, and appropriate constitutive equations. The solution technique is a time-dependent finite element analysis utilizing three-dimensional isoparametric elements, in conjunction with a generalized two-step time integration scheme. The developed code was demonstrated by solving one-dimensional as well as three-dimensional impact problems for both the inviscid hydrodynamic model and the hydroelasto-viscoplastic model.

76-1875

Finite-Element Models for NUSC Vibration Experiments on Thin-Line Towed-Array Modules

C.S. Nichols, R.R. Smith and D. Barach
Naval Undersea Ctr., San Diego, CA., Rept. No. NUC-TP-496, 72 pp (Jan 1976)
AD-A022 662/1GA

Key Words: Sonar arrays, Towed bodies, Finite element technique, Mathematical models, Vibration response

Finite-element models were developed for thin-line towed-array modules. The modules that have been considered are a 15-ft hose strength member module, a 30-ft internal strength member module, and three different configurations for a 5-ft internal strength member module. The theoretical predictions of these models for impedance, transmissibility, longitudinal displacement and pressure level were compared to experimental measurements on these modules that were obtained at NUSC. Good agreement is obtained between the theoretical predictions and the experimental measurements. It is shown that the size of the spacer hole is an important parameter in determining the pressure level in an internal strength member module.

76-1876

Finite Element Analysis of Elastic-Plastic Wave Propagation Effects

H. Armen and H. Garnet
Materials and Structural Mechanics, Grumman Aerospace Corp., Bethpage, NY, 11714, Computers and Struct., 6 (1), pp 45-53 (Feb 1976) 15 figs, 20 refs

Key Words: Mathematical modeling, Finite element technique, Dynamic response, Wave propagation

The feasibility of dynamic analysis by means of the finite element method, in conjunction with direct time step integration procedures, has been demonstrated and documented in the literature. However, there appears to be some uncertainty concerning the validity of such analyses in cases involving wave propagation effects. It is the purpose of this paper to demonstrate that under appropriate conditions, nonlinear finite element analysis techniques, utilizing a variable time step integration procedure, may be applied to obtain a reliable description of the response of a body undergoing wave propagation effects.

MODELING

(See Nos. 1902, 1925, 1996)

DIGITAL SIMULATION

(See No. 2015)

PARAMETER IDENTIFICATION

(Also see Nos. 1965, 1966, 2011)

76-1877

Distributed System Identification: A Green's Function Approach

G.R. Spalding
Dept. of Engrg., Wright State Univ., Dayton, OH
J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 146-151 (June 1976) 8 refs

Key Words: System identification, Continuous parameter method, Green function

A method is presented for identifying linear distributed parameter systems. Emphasis is placed on identification as a function of spatial coordinates by considering time-transformed, noise-free systems. Measurements of system response are combined with the Green's function method of analysis to obtain integral equations that can be solved for unknown spatial operators or coefficients. A discrete form of the theory is developed, utilizing Chebyshev polynomials. This allows prior estimates to be used to determine the number and location of spatial measurements.

76-1878

Frequency-Domain Synthesis of Optimal Inputs for Linear System Parameter Estimation

R.K. Mehra

Div. of Engrg. and Applied Physics, Harvard Univ., Cambridge, MA., J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 130-138 (June 1976) 1 fig, 24 refs

Key Words: Parameter identification, Dynamic systems, Structural synthesis, Frequency domain

This paper formulates the problem of estimating parameters in linear single-input multi-output dynamic systems as a regression problem in frequency domain. An expression for the information matrix is derived and its properties are studied. A frequency domain condition on the input for the nonsingularity of the information matrix is obtained.

DESIGN INFORMATION

(See No. 1991)

CRITERIA, STANDARDS, AND SPECIFICATIONS

(See No. 1975)

SURVEYS

76-1879

Structural Mechanics Software. Volume 1. March 1971-April 1975 (A Bibliography with Abstracts)

D.W. Grooms

NTIS, Springfield, VA, Rept. for Mar 1971 - Apr 1975, 190 pp (June 1976)

NTIS/PS-76/0436/6GA

Key Words: Bibliographies, Computer programs, Finite element techniques, Dynamic analysis

The use of computer programs in structural analysis-design problems are cited. Included are detailed analyses of structural problems, applied and theoretical, in many areas using finite elements and other numerical techniques. (This updated bibliography contains 185 abstracts, none of which are new entries to the previous edition.)

76-1880

Structural Mechanics Software. Volume 2. May 1975-May 1976 (A Bibliography with Abstracts)

D.W. Grooms

NTIS, Springfield, VA., Rept. for May 1975 - May 1976, 82 pp (June 1976)

(Supersedes NTIS/PS-74/428 and COM-74-10833) NTIS/PS-76-0437/4GA

Key Words: Bibliographies, Computer programs

The use of computer programs in structural analysis-design problems are cited. Included are detailed analyses of structural problems -- applied and theoretical -- including stress analysis, vibration problems, shear stress analysis, deformation analysis and others. The major computer programs cited in this report are NASTRAN, EPSOLA, SUPER-SCEPTRE, and SINGER. (This updated bibliography contains 77 abstracts, all of which are new entries to the previous edition.)

76-1881

Highway Safety Structures (A Bibliography with Abstracts)

G.H. Adams

NTIS, Springfield, VA., 147 pp (Apr 1976)

NTIS/PS-76/0295/6GA

Key Words: Collision research (automotive), Highway transportation, Bibliography

Documentation is made of various structures and mechanical devices for promoting highway safety. Reports pertain to highway signs and displays, barriers, medians, breakaway poles and supports, crash cushions, parapets, guard rails, curbs, and fences. Discussions are presented of impact attenuators, diagrammatic signs, glare screens, high intensity sheeting, and arrester beds. Also noted are retroreflective color coded signs, median grates, louvered signs, redirecting curbs, and other installations. Some attention is given to tests and methodology. (Contains 142 abstracts)

76-1882

Acoustic Holography (Citations from the Engineering Index Data Base)

E.J. Lehmann

NTIS Springfield, VA., Rept. for 1970 - May 1976, 166 pp (June 1976) See also NTIS/PS-76/0440

NTIS/PS-76-0441/6GA

Key Words: Acoustic holography, Testing techniques, Bibliography

Worldwide research on acoustic holography is covered. Theory, uses, equipment design, and imaging techniques are presented. Most of the studies are general and not applied to a specific use of acoustic holography. However, there are citations which do discuss its use in medicine, nuclear reactors, and nondestructive testing. (Contains 161 abstracts)

76-1883

Acoustic Holography (Citations from the NTIS Data Base)

D.M. Craig and E.J. Lehmann

NTIS, Springfield, VA, Rept. for 1974 - May 1976
107 pp (June 1976) (Also see NTIS/PS-76/0441.
Supersedes NTIS/PS-75/432 and COM-74-10871)
NTIS/PS-76-0440/8GA

Key Words: Acoustic holography, Bibliographies

All aspects of acoustic holography are covered in this bibliography of Federally-funded research. Theory, equipment design, uses, and imaging techniques are presented. The applications include underwater and underground object locating, structural geology and tectonics, sonar imaging, non-destructive testing, antenna radiation patterns, nuclear reactor inspection, remote sensing, and a use in medical examinations. (This updated bibliography contains 102 abstracts, 38 of which are new entries to the previous edition.)

76-1884

Publications in Acoustics and Noise Control from the NASA Langley Research Center during 1940-1974

G.C. Smith and J.N. LaNeave

NASA Langley Res. Ctr., Langley Station, VA
Rept. No. NASA-TM-X-72710, 71 pp (July 1975)
N76-23942

Key Words: Noise control, Ducts, Blades, Aircraft noise, Sonic boom, Structural response, Human response

This document contains reference lists of published Langley Research Center papers in various areas of acoustics and noise control for the period 1940-1974. The research work was performed either in-house by the center staff or by other personnel supported entirely or in part by grants or contracts.

76-1885

Recent Advances in the Technology of Aircraft Noise Control

R.E. Pendley

Douglas Aircraft Co., Long Beach, CA., J. Aircraft, 13 (7), pp 513-519 (July 1976) 16 figs, 25 refs

Key Words: Aircraft noise, Noise reduction, Engine noise, Fans, Compressors, Turbines

Continuing research and development programs dealing with the technology of aircraft noise control have yielded recent significant advances. Certain noise sources about which little was known previously have become better understood. Concepts leading to more efficient noise suppression have been defined. This paper surveys recent results from a number of research and development programs active within industry and government. The paper discusses advances relating to the prediction and suppression of noise generated by engine components (fans, compressors, turbines, combustors, and jets). In addition, it discusses recent advances in the understanding of the noise generated by the aerodynamic flow over airframe components.

TUTORIAL

76-1886

Department of Transportation Surface Transportation Noise Abatement Programs

W.H. Close

Office of Noise Abatement, Dept. of Transportation, Washington, D.C., Noise Control Engr., 6 (2), pp 81-85 (Mar-Apr 1976)

Key Words: Noise reduction, Traffic noise

Several divisions of the Department of Transportation and their functions with respect to noise control are surveyed.

COMPUTER PROGRAMS

GENERAL

(Also see Nos. 1880, 1911, 1968)

76-1887

Computational Predictions of Shock Diffraction Loading on an S-280 Electrical Equipment Shelter
R.E. Lottero

Ballistic Research Labs., Aberdeen Proving Ground, MD., Rept. No. BRL-MR-2599, 39 pp (Mar 1976)
AD-A022 804/9GA

Key Words: Computer programs, Equipment response, Shock response

The Los Alamos Scientific Laboratory, under contract to the BRL, utilized a three-dimensional, transient, hydrodynamics computer program, BAAL, developed at LASL, to compute the diffraction loading versus time caused by a one-dimensional 34.475 kPa (5.0 psi) overpressure steady shock wave striking an S-280 Electrical Equipment Shelter.

76-1888

Community Noise Exposure Resulting from Aircraft Operations. Appendix: NOISEMAP Program Operator's Manual

N.H. Reddingius

Bolt Beranek and Newman, Inc., Canoga Park, CA
Rept. No. BBN-2946, AMRL-TR-73-108-App, 29 pp (Feb 1976)

AD-A022 911/2GA

Key Words: Computer programs, Aircraft noise

This report delineates the program operator changes consistent with the additional developments made on the computer program described in AMRL-TR-73-108 (AD-A004 821). The added capabilities and improved diagnostics that form NOISEMAP 3.2 are discussed. NOISEMAP 3.2 is used Air Force-wide to compute community noise exposure from aircraft flying and ground runup operations for preparing/assessing candidate. Environmental Impact Statements and planning compatible land use in the vicinity of air installations.

76-1889

A Computer Program to Automate a Method for Predicting Acoustically Induced Vibration in Transport Aircraft

T. Harris

Air Force Flight Dynamics Lab., Wright-Patterson AFB, OH., Rept. No. AFFDL-TM-75-111-FYS, 53 pp (Jan 1976) (Also see rept. dated Sept 1974, AD-A004 215)

AD-A022 571/4GA

Key Words: Transport aircraft, Vibration response, Acoustic excitation, Computer programs

The report presents a computer program which automates a vibration prediction method. Inputs to the program are estimates of fluctuating pressure levels in third-octave bands. These may be either sound pressure levels from the engines or the levels of aerodynamic flow turbulence. In addition, for new aircraft with structures which differ appreciably from contemporary transport designs, values of parameters which characterize the mass and rigidity of the new structure may be input to the program.

NATURAL FREQUENCY

76-1890

Data Errors in the Computation of Free Motion

W. Gawronski

Technical Univ. of Gdansk, Inst. of Mechanics and Machine Design, 80-952 Gdansk, Poland, Computers and Struc., 6 (1), pp 17-27 (Feb 1976) 8 figs, 14 refs

Key Words: Error analysis, Natural frequencies, Mode shapes, Finite element technique, Computer programs

Input data in the computation of free motion (the inertia and stiffness matrices) contain some errors. These errors generate errors of output data (the natural frequency vector, the natural mode vectors). In this paper the relationships between errors of input and output data in the computation of free motion are derived. This analysis is applied to the finite element method. The paper presents program ERROR, which computes the errors of the natural frequencies created by the inertia matrix errors. An example of the influence of the errors of the mass and of the mass moment of inertia on the natural frequencies of a ship hull is presented.

ENVIRONMENTS

ACOUSTIC

(Also see Nos. 1882, 1883, 1888, 1906, 1941, 1950, 1964, 1977, 1978, 1979, 1982, 1998)

76-1891

Fluid Mechanical Model of the Acoustic Impedance of Small Orifices

A.S. Hersh and T. Rogers

Hersh Acoustical Engineering, Chatsworth, CA.
Rept. No. NASA-CR-2682, 57 pp (May 1976)

N76-23947

Key Words: Holes, Acoustic impedance

A fluid mechanical model of the acoustic behavior of small orifices is presented which predicts orifice resistance and reactance as a function of incident sound pressure level, frequency, and orifice geometry. Agreement between predicted and measured values is excellent.

76-1892

Sonic Boom Propagation at Low Supersonic Speeds

N.W. Page

Aeronautical Res. Labs., Melbourne, Australia, Rept.
No. ARL/A-143, 37 pp (May 1975)

N76-21203

Key Words: Sonic boom, Noise generation, Sound waves, Wave propagation

Atmospheric and flight conditions necessary to cause refraction of ray paths sufficient to reverse their vertical direction are examined. Analytical solutions were obtained for the height for vertical reversal of ray paths emanating from an aircraft flying at Mach numbers between 1 and 1.15 in a standard atmosphere with horizontal winds varying linearly with altitude. Both the height for vertical reversal of ray paths and ray path curvature were found to depend on a single non-dimensional refraction parameter which expresses the relative importance of refraction caused by vertical gradients of wind and temperature.

76-1893

Study of Community Noise Complaints Caused by Electric Power Plant Operations

R.M. Hoover

Bolt Beranek and Newman, Inc., 3344 Crossview,
Houston, TX., Noise Control Engr., 6 (2), pp 74-80
(Mar-Apr 1976) 9 figs, 4 refs

Key Words: Electric power plants, Noise generation

The main results of a study of a number of documented cases of community complaints about noise due to power-plant operations are presented. The specific purpose of this study was to show the range of A-weighted sound levels at locations in the community where complaints had been made, to provide one guide for the evaluation of proposed design limits for the exterior noise of power-plant operations.

SEISMIC

(See Nos. 1905, 1991, 1992)

SHOCK

(Also see Nos. 1874, 1885, 1908, 1993)

76-1894

Design Study of a Suppressive Structure for a Melt Loading Operation

W.E. Baker, P.A. Cox, E.D. Esparza and P.S. Westline
Southwest Research Inst., San Antonio, TX., Rept.
No. TR-9, EM-CR-76043, 74 pp (Dec 1975) (Also
see rept. dated Nov. 1975, AD-A022 333)

AD-A024 378/2GA

Key Words: Dynamic response, Blast loads, Explosion effects, Beams, Cylinders, Roofs

This report presents the results of a design study for a structure to suppress blast and fragment effects from detonation of a large quantity of Comp B explosive in a melt kettle. A number of design concepts were evaluated, and a specific configuration recommended. Relatively detailed design drawings were prepared.

TRANSPORTATION

(See No. 2001)

PHENOMENOLOGY

DAMPING

(Also see No. 2029)

76-1895

Study on Passive Nutation Dampers. Volume 1: Literature Survey and Analysis

L.J. Ancher, H. vdBrink and A. Pouw

Space Div., Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost., Rept. No. FOK-RV-75-110-Vol-1; ESA-CR(P)-788-Vol-1, 218 pp (Dec 1975) N76-22291

Key Words: Nutation dampers, Bibliographies, Spacecraft equipment

Passive type nutation dampers were analyzed for single spin satellites. A literature survey was carried out, and a list of criteria was compiled and used for a comparison of damper types. The following damper types were selected for further study since they are the most promising in terms of mass, performance, and reliability for future missions; pendulum with eddy current damping, tube with endpots damper, and partly filled annular damper. A mass-spring-dashpot damper was also studied. For each type, the damper-only equation was derived after decoupling the satellite motion and the damper motion. The coupled equations of motion were derived. The Routh-Hurwitz stability criterion was analyzed for the mass-spring-dashpot damper using linearized equations of motion. Existing methods of simulating the flight performance of the damper on the ground are outlined. For volumes 2 and 3, see ESR-96981 and ESR-96982.

76-1896

Study on Passive Nutation Dampers. Volume 2: Damper Selection and Dimensioning

L.J. Ancher, H. vdBrink and A. Pouw

Space Div., Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost., Rept. No. FOK-RV-75-110-Vol-2; ESA-CR(P)-788-Vol-2, 213 pp (Dec 1975) N76-22292

Key Words: Nutation dampers, Bibliographies, Spacecraft equipment

Passive type nutation dampers were analyzed for single spin satellites. Types studied are: pendulum with eddy current damping, tube with endpots damper, and partly filled annular damper. A mass-spring-dashpot damper was also considered. A selection and dimensioning procedure of damper type is presented. The type of damper which should preferably be used in a given mission depends on both mission requirements and satellite parameters. A rigorous and a simplified dimensioning procedure is given for the pendulum and tube with endpots damper. The selection and dimensioning procedure is exemplified for three satellite missions defined by ESTEC. For volumes 1 and 3, see ESR-96980 and ESR-96982.

76-1897

Study on Passive Nutation Dampers. Volume 3: Appendices

L.J. Ancher, H. vdBrink and A. Pouw

Space Div., Royal Netherlands Aircraft Factories Fokker, Schiphol-Oost., Rept. No. FOK-RV-74-110-Vol-3-APP; ESA-CR(P)-788-Vol-3-App, 128 pp (Dec 1975) N76-22293

Key Words: Nutation dampers, Bibliographies, Spacecraft equipment

Passive type nutation dampers were analyzed for single spin satellites. Types studied are: pendulum with eddy current damping, tube with endpots damper, and partly filled annular damper. A mass-spring-dashpot damper was also considered. A literature matrix covering details of 108 publications studied is presented. Also included are mathematical details concerning mainly equations of motion of the various damper types. For volumes 1 and 2; see ESR-96980 and ESR-96981.

FLUID

(Also see Nos. 1921, 1938, 1939, 1940)

76-1898

Wave Forces on Models of Submerged Offshore Structures

P.E. Versowsky and J.B. Herbich

Coastal, Hydraulic and Ocean Engrg. Group, Texas A&M Univ., College Station, TX., Rept. No. TAMU-SG-74-215, COE-175, NOAA-76030304, 135 pp (Aug 1975) PB-253 059/OGA

Key Words: Underwater structures, Offshore structures, Water waves, Model testing (testing of models)

The results of a model study of the forces caused by oscillatory waves on large rectangular tank-like submerged objects are presented. Three phases of the problem were examined: (1) description of the forces in terms of dimensionless parameters, (2) description of the effect of large wave heights which are of importance to the designer, and (3) the presentation of a format to be used in model studies on submerged structures. Theoretical studies of the problem have assumed wave heights to be small and the forces to be entirely inertial. However, of interest to the engineer are the forces caused by the larger waves generated by severe storms. In the model study the forces caused by the larger waves were determined and the effect of the water particle velocity in producing a drag force was examined. The relationships between the fluid particle displacement and the coefficients of mass and drag were evaluated.

76-1899

Cyclic Squeeze Films in Micropolar Fluid Lubricated Journal Bearings

J. Prakash and P. Sinha

Dept. of Machine Design, The Engrg. Research Foundation at the Technical Univ. of Norway, Trondheim, Norway, J. Lubric. Tech., Trans. ASME, 98 (3), pp 412-417 (July 1976) 10 figs, 14 refs

Key Words: Lubrication, Squeeze-film bearings, Journal bearings

The Reynolds equation for the general case of dynamic loading is derived for fluid suspensions, using the micropolar fluid theory. Detailed consideration is given to the dynamic behavior of squeeze films in journal bearings under a fluctuating load with no journal rotation. The characteristics of an infinitely long journal bearing under a cyclic sinusoidal load are shown in curve form, so as to elaborate the micropolar effects.

76-1900

Dynamic Analysis of Elastohydrodynamic Squeeze Films

S.M. Rohde, D. Whicker and A.L. Browne

Engrg. Mechanics Dept. Res. Labs., General Motors Corp., Warren, MI., J. Lubric. Tech., Trans. ASME, 98 (3), pp 401-408 (July 1976) 8 figs, 11 refs
ASME Paper No. 75-Lub-5

Key Words: Elastohydrodynamic properties, Lubrication, Transient response, Squeeze-film bearings

This paper contains an analysis of a class of elastohydrodynamic squeeze film problems. A transient analysis is presented. Thick films bounded by a finite rigid plate and a compliant half-space are considered. The effect of different approach constraints is explored, among these being constant and time varying load and constant and time varying center point pressure. The effect of different material models is also considered.

76-1901

Stability Analysis and Optimization of By-Pass Controlled Heat Exchanger with Boiling

J.S. Ansari

School of Automation, Indian Inst. of Science, Bangalore, India, J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 161-166 (June 1976) 3 figs, 7 refs

Key Words: Heat exchangers, Stability, Optimization, Mathematical models

A heat exchanger with boiling is considered. The final temperature of steam is controlled with the help of a controller which regulates the flow rate of by-pass water mixing with the outcoming steam. The simplest known mathematical model retaining the nonlinear and distributed parameter nature of the process is adopted. A known method of analysis, namely, Liapunov-Razumikhin theorem, is used to derive results on stability. An interesting feature of the system is that a positive feedback is required for stability. If the control is designed on the basis of minimization of the error in the final temperature alone, then the optimal control, requiring a negative feedback, leads to sustained oscillations in the intermediate variables, even when the output is steady. The analysis, therefore suggests that meaningful optimization must take into account fluctuations in intermediate variables in addition to the error. A derivative control is shown to improve the transient response.

SOIL

(Also see Nos. 1901, 2028)

76-1902

Dynamic Behavior of Partially Embedded Pile

M.A. Satter

Dept. of Mech. Engrg., Pahlavi Univ., Shiraz, Iran
ASCE J. Geotech. Engr. Div., 102 (GT7), pp 775-785 (July 1976)
Paper No. 11265

Key Words: Pile structures, Pile driving, Interaction: soil-structure, Vibration response, Mathematical models

Vibrational behavior of a partially embedded pile has been studied theoretically and some of the results compared with available field data. A mathematical model incorporating "pile-soil interaction" for resonant pile driving has been proposed. Only the longitudinal mode of the pile has been considered, but the same theory may be modified slightly to predict torsional behavior as well. The model equation is solved through standard Fourier transform method. Certain simplification has been introduced to the solution to minimize computational effort while retaining good accuracy.

76-1903

Multiple Diffractions of Elastic Shear Waves by a Rigid Rectangular Foundation Embedded in an Elastic Half Space

M. Dravinski and S.A. Thau

Div. of Engrg. and Applied Science, California Inst. of Technology, Pasadena, CA., J. Appl. Mech., Trans. ASME, 43 (2), pp 295-299 (June 1976) 3 figs, 5 refs

Sponsored by the National Science Foundation

Key Words: Foundations, Interaction: soil-structure, Wave diffraction, Elastic waves

A rigid rectangular foundation, embedded in an elastic half space, is subjected to a plane, transverse, horizontally polarized shear (SH) wave. Embedment depth of the foundation and the angle of the incidence of the plane wave are assumed to be arbitrary. The problem considered is of the antiplane-strain type. The Laplace and Kontorovich-Lebedev transforms are employed to derive the equation of motion for the foundation during the period of time required for an SH-wave to traverse the base width of the obstacle twice. Therefore this solution includes the process of multiple diffractions at the corners of the foundation.

76-1904

Multiple Diffractions of Elastic Waves by a Rigid Rectangular Foundation: Plane-Strain Model

M. Dravinski and S.A. Thau

Div. of Engrg. and Applied Science, California Inst. of Technology, Pasadena, CA., J. Appl. Mech., Trans. ASME, 43 (2), pp 291-294 (June 1976) 3 figs, 4 refs

Sponsored by the National Science Foundation

Key Words: Interaction: soil-structure, Foundations, Wave diffraction, Elastic waves

A rigid rectangular foundation embedded in an elastic half space moves in a direction perpendicular to the surface of the half space. The model under consideration is of the plane-strain type. By application of the Laplace, Fourier, and Kontorovich-Lebedev (K-L) transforms, the equation of motion for the foundation is derived. The transient response of the foundation is exact during the period of time required for a longitudinal wave to traverse the base of the foundation twice. Thus the process of multiple diffractions at the corners of the foundation is taken into account.

76-1905

Seismic Response and Liquefaction of Sands

W.D.L. Finn, P.M. Byrne and G.R. Martin

Dept. of Appl. Sci., Univ. of British Columbia, Vancouver, Canada, ASCE J. Geotech. Engr. Div., 102 (GT8), pp 841-856 (Aug 1976) 14 figs, 14 refs

Key Words: Sand, Seismic response

An effective stress analysis has been developed for determining the dynamic response of horizontal saturated sand deposits to earthquake motions consisting of vertically propagating shear waves. A hyperbolic stress-strain law is used for sands in shear and during the earthquake motions the modulus and damping properties of the sands are modified continuously for the effects of dynamic shear strains and pore-water pressures. The pore-water pressures are continuously updated using equations which relate pore-water pressures to dynamic shear strain history.

VISCOELASTIC

(Also see No. 2027)

76-1906

Vibration of Elastic Bodies with Small Viscoelastic Effects

S. Cerneau and E. Sanchez-Palencia

Ecole Normale Supérieure de Fontenay-aux-Roses et Laboratoire de Mécanique Théorique, associé au C.N.R.S., J. Mécanique, 15 (2), pp 237-263 (1976) 20 refs

(In French)

Key Words: Acoustic properties, Viscoelasticity

The vibrations of elastic bodies whose equations of motion contain a small viscoelastic term are studied. By using the two-scale expansion method, the acoustic properties of the sound associated with the vibration are studied; as the oscillations decay, the sound tends to have a finite number of well-determined frequencies.

EXPERIMENTATION

DIAGNOSTICS

(Also see No. 1920)

76-1907

Proceedings of the 22d Meeting of the Mechanical Failures Prevention Group

T.R. Shives and W.A. Williard

Metallurgy Div., NASA, Goddard Space Flight Ctr., Greenbelt, MD., Rept. No. NASA-TM-X073005; PB-248254/5; CNBS-SP-436, 369 pp (Dec 1975) N76-22563

Key Words: Diagnostic techniques, Proceedings

These Proceedings consist of a group of nineteen submitted papers and discussions from the 22nd meeting of the Mechanical Failures Prevention Group which was held at the Grand Hotel in Anaheim, California on April 23-25, 1975. Failure detection, diagnosis, and prognosis represent the central theme of the Proceedings. Technology and techniques, ongoing diagnostic programs, and coming requirements in the field of diagnostics and preventive maintenance are discussed. In addition, several case histories are presented.

FACILITIES

76-1908

Exploding Wire Shock Test Facility

R.A. Boardman

Cushing Engrg. Inc., Northbrook, IL., Contract No. N00014-73-C-0402, 34 pp (April 15, 1976) AD-A024 924/3GA

Key Words: Shock tests, Test facilities, Underwater explosions

The Cushing Engineering Company Shock Test Facility has recently been assembled and demonstrated at Naval Research Laboratory, Washington, D.C. for the purpose of investigating and testing underwater explosion phenomena from a pure energy yield explosion source. In conjunction

with these experiments, formulas were developed to accurately scale the data results from these tests to approximate large nuclear explosions. The attendant instrumentation for this facility, presently available, allows for the study of gas bubble dynamics, surface wave and shock wave propagation, rarefaction shock wave generated cavitation and column formation. The purpose of this document is to describe the aforementioned test facility equipment in regard to its construction, alignment and operational sequence.

76-1909

Note on Aero-Acoustic Measurements in Openjet Wind Tunnels

H.V. Fuchs

Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Berlin, W. Germany, Inst. fuer Turbulenzforschung, Rept. No. DLR-IB-357-74/4, 29 pp (1974) N76-22980

Key Words: Acoustic measurement, Wind tunnels

Sound measurements in a turbulent air flow are discussed. Problem areas include acoustic contamination, turbulent flow pressures, and probe flow interference. Possible probe developments for in-flow noise measurements are indicated, and a short survey of activities in pressure fluctuation and sound measurements inside airflows is given.

76-1910

The New Transonic and Supersonic Wind Tunnel of the Aerodynamic Institute

G. Freytag

Agnew Tech-Tran., Inc., Woodland Hills, CA., Rept. No. NASA-TT-F-16977, 18 pp (Apr 1976) (Engl. transl. from Rheinisch-Westfalische Tech. Hochschule, Abhandlungen (Aachen), no. 22, 1975, pp 233-238) N76-21222

Key Words: Wind tunnels

The available compressor installations restrict the use of the new wind tunnel to an intermittent operation schedule. Operational details are discussed, taking into account the employment of suction and pressure. The design of the wind tunnel is considered, giving attention to the Laval nozzle, the free jet chamber, the diffusor, and the transonic chamber.

76-1911

Sting Dynamics of Wind Tunnel Models

J.P. Billingsley

Arnold Engrg. Dev. Ctr., Arnold Air Force Station, TN., Rept. No. AEDC-TR-76-41, 65 pp (May 1976) (Prepared in cooperation with ARO, Inc., Tullahoma, TN, Rept. No. ARO-VKF-TR-75-150) AD-A024 455/9GA

Key Words: Wind tunnel tests, Mountings, Oscillation, Computer programs

Wind tunnel model support stings can be subjected to transient aerodynamic and inertial loads which will create oscillatory translations and angular deflections. These transient oscillations always impair steady-state data accuracy and can be large enough to cause structural failure. The primary result of this investigation has been the formulation of a mathematical analysis for the dynamic response of sting-balance combinations subjected to arbitrary transient load inputs. The analysis also provides for sting rigid body motion so that model to tunnel injection and continuous sting rotation can be simulated. A computer program was written to numerically solve the sting-model-balance motion equations.

76-1912

Design and Preliminary Test Results at Mach 5 of an Axisymmetric Slotted Sound Shield

I.E. Beckwith, A.J. Spokowski, W.D. Harvey, and P.C. Stainback

NASA, Langley Res. Ctr., Langley Station, VA., Rept. No. NASA-TM-X-72679, 64 pp (June 1975) N76-22217

Key Words: Acoustic absorption, Noise barriers, Wind tunnels

The basic theory and sound attenuation mechanisms, the design procedures, and preliminary experimental results are presented for a small axisymmetric sound shield for supersonic wind tunnels.

76-1913

Analysis of a Platform for Measuring Moments and Products of Inertia of Large Vehicles

D. Orne and T. Schmitz

Dept. of Mech. Engrg. Sciences, Wayne State Univ., Detroit, MI., J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 186-195 (June 1976), 10 figs, 5 refs

Key Words: Test facilities, Ground vehicles, System identification, Inertial forces, Vibratory techniques

A rigid platform symmetrically supported by four sloping cables is proposed for measuring the center-of-gravity coordinates and the moments and products of inertia of large vehicles such as buses, trucks, and trailers. In addition to a torsional degree-of-freedom, the system undergoes pitch and roll motions about axes through the system instantaneous center which lies directly below the center of the platform at the intersection of the cable lines-of-action under quiescent conditions. The natural frequencies and normal modes of the freely vibrating loaded platform are used as inputs to a linearized System Identification Algorithm for computing the inertia properties of the test vehicle. Hypothetical test data generated from the Free Vibration Analysis of a sample test configuration are used to evaluate the sensitivity of the System Identification Algorithm to inaccuracies in test data or to truncation errors in computation.

76-1914

Impact Dynamics Research Facility for Full-Scale Aircraft Crash Testing

V.L. Vaughan, Jr. and E. Alfaro-Bou

NASA, Langley Res. Ctr., Langley Station, VA., Rept. No. NASA-TN-D-8179; L-10514, 56 pp (Apr 1976)

N76-21173

Key Words: Test facilities, Aircraft, Crash research (aircraft)

An impact dynamics research facility (IDRF) was developed to crash test full-scale general aviation aircraft under free-flight test conditions. The aircraft are crashed into the impact surface as free bodies; a pendulum swing method is used to obtain desired flight paths and velocities. Flight paths up to -69 deg and aircraft velocities along the flight paths up to about 27.0 m/s can be obtained with a combination of swing-cable lengths and release heights made available by a large gantry. Seven twin engine, 2721-kg aircraft were successfully crash tested at the facility, and all systems functioned properly.

INSTRUMENTATION

(Also see Nos. 1873, 1887, 2031)

76-1915

New, Compact Instrument for Pulse-Echo-Overlap Measurements of Ultrasonic Wave Transit Times

E.P. Papadakis

Ford Motor Co., 24500 Glendale Ave., Detroit, MI 48239, Rev. Sci. Instr., 47 (7), pp 806-813 (July 1976) 8 figs, 16 refs

Key Words: Measuring instruments, Pulse test methods, Phase velocity

A new instrument is described which permits the travel time of ultrasonic waves to be measured accurately and conveniently by the pulse-echo-overlap method (PEO). The accuracy and versatility of the PEO method are reviewed, and optimal methods of preparing and interrogating samples are presented. Extensive data on a large blank of fused silica are presented. Longitudinal and shear wave velocities were calculated from the wave travel times through measured thicknesses, and the elastic moduli were subsequently calculated from the velocities and the measured density.

76-1916

Frequency Doubling—A New Approach to Vibrating Sample Magnetometers

C.N. Guy

Physics Dept., Imperial College, London SW7 2BZ, England, J. Phys. E., (Sci Instr.), 9 (6), pp 433-435 (June 1976) 4 figs, 6 refs

Key Words: Measuring instruments

It is shown that a general treatment of the properties of vibrating sample magnetometer pickup coils, leads to the possibility of induced signals at twice the frequency of sample vibration. Possible applications of this effect to two sample magnetometers and magnetic anisotropy measurements are discussed.

SIMULATORS

(See No. 1918)

TECHNIQUES

(Also see Nos. 1882, 1883, 1909, 1973, 2030)

76-1917

Dynamic Simulation in Windtunnels, Part I

H. Hoenlinger and O. Sensburg

Messerschmitt-Boelkow-Blohm G.m.b.H., Unternehmensbereich Flugzeuge, Ottobrunn, W. Germany Rept. No. MBB-UFE-1180-0, 20 pp (Apr 1975) (Presented at the AGARD Flight Mech. Panel Symp. on Flight/Ground Testing Facilities Correlation, Valloire/Modane, France, 9-12 June 1975) N76-21192

Key Words: Flutter, Testing techniques, Wind tunnel tests, Aircraft wings, Wing stores

The techniques used to investigate flutter characteristics and flutter suppression systems are described. Two cases in which active flutter suppression was successfully applied are demonstrated. One case deals with the flutter of a wing with a store and the other with an empennage flutter case.

76-1918

Automated Dynamic Load Simulator—A Useful Tool in Evaluating Cranking System Design

S.M. Chohan

General Motors Corp., McCook, IL., ASME Paper No. 76-DE-13

Key Words: Automated testing, Testing techniques, Internal combustion engines

An automated dynamic load simulator was designed and constructed for laboratory endurance testing of internal combustion engine cranking system. This paper provides a description of the simulator from conceptual as well as hardware standpoints.

76-1919

Determination of the Dynamic Structural Response Characteristics of a Large Diesel Engine by Means of the Low Level Impedance Method

R.T.M. Yang

Delaval Turbine Inc., Oakland, CA., ASME Paper No. 76-DGP-9

Key Words: Diesel engines, Frequency response, Measurement techniques

This paper describes the combination physical and analytical approach used to determine the dynamic structural response of a large and complex structure like the diesel engines and auxiliaries. Due to the size and complexity of the diesel engine, the conventional shake table and modal analysis cannot accurately predict the dynamic characteristics of the system. This method enables accurate measurement of the frequency response at the various points of interest on the engine system. For nuclear standby power application, the diesel generator system will have to be seismically qualified for structural adequacy. The results of this test enable the necessary modifications and adjustments to the mathematical model, so that an accurate prediction of structural characteristics can be achieved.

76-1920

Comparison of Acoustic and Strain Gauge Techniques for Crack Closure Measurements

O. Buck, R.V. Inman, and J.D. Frandsen

Science Ctr., Rockwell Intl. Corp., Thousand Oaks, CA, Rept. No. NASA-CR-144968; SC5032.22FR, 40 pp (May 10, 1976)

N76-22581

Key Words: Diagnostic techniques, Acoustic techniques, Crack detection, Measuring techniques

A quantitative study on the systems performances of the COD gauge and the acoustic transmission techniques to elastic deformation of part-through crack and compact tension specimens has been conducted. It is shown that the two instruments measure two completely different quantities: The COD gauge yields information on the length change of the specimen whereas the acoustic technique is sensitive directly to the amount of contact area between two surfaces, interfering with the acoustic signal. In another series of experiments, compression tests on parts with specifically prepared surfaces were performed.

COMPONENTS

BEAMS, STRINGS, RODS

(Also see Nos. 1957, 2024)

76-1921

Random Response of Offshore Structures to Wave and Current Forces

S.C. Wu and C.C. Tung

Dept. of Civil Engrg., North Carolina State Univ., Raleigh, NC, Rept. No. UNC-SG-75-22, NOAA-76022006, 125 pp (Sept 1975)

PB-252 331/4GA

Key Words: Offshore structures, Towers, Dynamic response

Dynamic responses of offshore structures to random waves and steady current are examined. The structural response quantities examined are the displacement, shear, and bending moment. The statistic sought is the peak response which is the quantity directly used in design considerations. Numerical results are obtained for four offshore towers, ranging in heights from 475 to 1075 feet, for various wave and current conditions. Results are presented graphically. It is shown that structural responses increase with increase in current speed but the effects of wave-current interactions are important only for tall slender structures. Also, the effects of current on structural response diminishes with increase in the strength of the waves.

76-1922

A Study of the Higher Modal Dynamic Plastic Response of Beams

N. Jones and T. Wierzbicki

Dept. of Ocean Engrg., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. 76-3, 40 pp (Apr 1976) AD-A025 204/9GA

Key Words: Beams, Modal analysis

A theoretical and experimental investigation into the higher modal dynamic plastic response of fully clamped beams is reported herein. It is shown that the influence of geometry changes or finite-deflections is important. It appears that the higher modal response of beams is a more efficient means of absorbing a given magnitude of kinetic energy than a single modal response.

76-1923

Elastic-Plastic Response of 6061-T6 Aluminum Beams to Impulse Loads

M.J. Forrestal and D.L. Wesenberg

Simulation Research Dept., Sandia Laboratories, Albuquerque, NM, J. Appl. Mech., Trans. ASME, 43, (2), pp 259-262 (June 1976) 6 figs, 15 refs

Key Words: Beams, Pulse excitation, Shock excitation, Elastic plastic properties

The elastic-plastic response of 6061-T6 aluminum beams is examined experimentally and analytically. Simply supported beams are loaded with half-sine wave, short-duration magnetic pressure pulses and the response is monitored with a framing camera and strain gages. A closed-form elastic-plastic approximate theory for peak displacement is derived and compared with measurements and a numerical analysis. Measured displacement-time and strain-time histories are also compared with numerical predictions. Good agreement is shown between measurements and predictions.

76-1924

Dynamic Behavior of Ideal Fibre-Reinforced Rigid-Plastic Beams

N. Jones

Dept. of Ocean Engrg., Massachusetts Inst. of Technology, Cambridge, MA., J. Appl. Mech., Trans. ASME, 43 (2), pp 319-324 (June 1976) 4 figs, 14 refs

Key Words: Beams, Fiber composites, Anisotropy, Dynamic plasticity

Theoretical solutions are developed herein for the dynamic plastic structural response of some ideal fibre-reinforced (strongly anisotropic) beams with boundary conditions and external dynamic loadings which can be reproduced easily and reliably in a laboratory. The theoretical behavior of these beams is compared to the corresponding dynamic response of beams which are made from a rigid perfectly plastic isotropic material.

76-1925

A Lumped Mass Vibration Model of a Slender Latticed Cantilever

M.A. Parameswaran and K. Sukumaran

Mechanical Engrg. Dept., Indian Inst. of Technology, Madras, India, Computers and Struc., 6 (2), pp 107-109 (Apr 1976) 4 figs

Key Words: Cantilever beams, Normal modes, Lumped mass method, Mathematical models

A relatively simple numerical iterative procedure for estimating the normal modes of flexural vibrations of a slender, multipanel latticed cantilever, tapered or straight, is developed. The cantilever is reduced to a N mass system and the influence coefficients are derived with due consideration to the shear flow through the diagonal bracings. Experimental and computer results on a model are compared.

76-1926

Optimum Support Damping for a Vibrating Beam

J.C. Macbain and J. Genin

Air Force Aero Propulsion Lab., Wright-Patterson AFB, OH., Rept. No. AFAPL-TR-76-14, 16 pp (Feb 1976)

AD-A025 106/6GA

Key Words: Cantilever beams, Vibration damping, Supports, Mathematical models, Lumped mass models

A method for determining the optimum support damping of a flexibly supported cantilever beam using an analogous lumped mass model is described. The optimum system damping is determined as a function of rotational end-fixity of the cantilever support interface. The damping value based on the lumped mass model is found to be in good agreement with the damping value based on a mathematical model of a continuous cantilever beam.

76-1927

Added Mass and Damping of a Vibrating Rod in Confined Viscous Fluids

S.S. Chen, M.W. Wambsganss and J.A. Jendrzejczyk
Components Technology Div., Argonne National Lab., Argonne, IL., J. Appl. Mech., Trans. ASME, 43 (2), pp 325-329 (June 1976) 5 figs, 10 refs

Key Words: Cantilever rods, Submerged structures, Viscous damping

This paper presents an analytical and experimental study of a cylindrical rod vibrating in a viscous fluid enclosed by a rigid, concentric cylindrical shell. A closed-form solution for the added mass and damping coefficient is obtained and a series of experiments with cantilevered rods vibrating in various viscous fluids is performed. Experimental data and theoretical results are in good agreement.

76-1928

On Dualities in the Oscillations of Naturally Curved and Pretwisted Rods

B. Tabarrok and M. Farshad

Dept. of Mechanical Engrg., Univ. of Toronto, Toronto, Canada, Intl. J. Solids Struc., 12 (8), pp 601-609 (1976) 1 fig, 13 refs

Key Words: Curved rods, Initial deformation effects, Equations of motion

The pertinent equations of naturally curved and pretwisted rods, in the form of compatibility, equilibrium and constitutive relations are obtained under the assumptions of infinitesimal deformations and material isotropy. Then by forming the expressions for various energy terms, the equations of motion of the rod are obtained via Hamilton's principle and the complementary energy principle. On comparing these two forms of equations of motion, and the associated boundary conditions certain dualities are exposed. Finally the equations of some special rods, including the plane arch and the straight pretwisted rod, are examined.

76-1929

The Vibration of Cylinders

G.M.L. Gladwell

Solid Mech. Div., Faculty of Engineering, Univ. of Waterloo, Ontario, Canada, Shock and Vibration Digest, 8 (8), pp 13-24 (Aug 1976) 18 figs, 37 refs

Key Words: Cylinders, Rods, Free vibration, Reviews

This survey is concerned with the vibrations, mostly free undamped vibrations, of solid and hollow circular cylinders, not with cylindrical shells; the term 'rod' will be used to denote a solid circular cylinder. Shell theories will be considered only insofar as their ability to predict the vibrations of cylinders.

76-1930

Nonlinear Vibration of Cable Trusses

S.H. Mote

Ph.D. Thesis, Illinois Institute of Technology, 1975, 62 pp
UM 76-13, 165

Key Words: Cables (ropes), Suspension bridges, Nonlinear response

This study concerns the vibration of cable trusses consisting of a top cable curved up, a bottom cable curved down and connected with diagonal members. The system is nonlinear in

that deformation can no longer be considered as small and must be taken into account in obtaining final deflections and stresses. In addition, the diagonals may be in and out of action during vibration.

76-1931

Phenomenological Investigation of the Resonance Effects on the Torsional Vibration Mode of a Cable Boom

D. Wyn-Robers and I. McVicar

Electronics and Space Systems Group, British Aircraft Corp., (Operating) Ltd., Bristol, England, Rept. No. ESS/SS-415; ESA-CR(P)-230, 141 pp (Dec 1972) N76-22551

Key Words: Cables (ropes), Spacecraft equipment, Equipment mounts, Torsional vibration

The purpose of the investigation was to examine the behavior of a variety of cable booms under the influence of mechanical and thermal excitation, for application to the GEOS satellite as supports for equipment sensors. The behavior of the cable under various conditions was investigated. Resonance modes were clearly identified with large amplitude magnification occurring for both torsion and lateral resonance conditions. Oscillating heating alone did not cause any movements of the cable even when induced in resonant frequencies. Reducing the tip inertia of the cable caused an expected increase in torsion resonance frequencies. A number of cases were highlighted where cross-coupling between lateral and torsion modes occurred.

BEARINGS

(Also see No. 1899)

76-1932

Bending Stresses in Spherically Hollow Ball Bearing and Fatigue Experiments

L.J. Nypan, H.H. Coe and R.J. Parker

California State Univ., Northridge, CA., J. Lubric. Tech., Trans. ASME, 98 (3), pp 472-475 (July 1976) 5 figs, 11 refs

ASME Paper No. 75-Lub-8

Key Words: Ball bearings, Fatigue tests

Spherically hollow balls of 21.7, 50.0 and 56.5 percent mass reduction have been operated in ball bearings and in a 5-ball fatigue tester with differing outcomes. Available theoretical and experimental treatments of stresses in spherically hollow balls are reviewed and compared. Bending stresses are estimated for these spherically hollow balls to better understand the differences in ball bearing and fatigue test experience.

76-1933

Prediction of Rolling Contact Fatigue Life in Contaminated Lubricant: Part II - Experimental

T.E. Tallian

Technology Services, SKF Industries, Inc., King of Prussia, PA., J. Lubric. Tech., Trans. ASME, 98 (3), pp 384-392 (July 1976) 11 figs, 16 refs

Sponsored by the U.S. Navy, Air Engineering Center, Philadelphia, PA

Key Words: Ball bearings, Lubrication, Fatigue life

In this second part of a two-part paper, experimental fatigue life data on ball bearings operated under different lubrication conditions are correlated to surface damage densities of life tested ball bearing inner rings, as determined by scanning electron microscopy. In Part I, five cases of a mathematical model for the prediction of fatigue life in contaminated bearings were presented. The models are fitted to the experimental data given in the present Part II. The correlation coefficient of experimental L_{10} life with model Case II predictions, based on observed defect densities, is of the order of 0.99 and highly significant for most test groups. One grease lubricated group requires fitting by model Case III. Predicted life dispersion exponents are too high compared to experiment. General data on lubricant contaminant densities show a sufficiency of particles to cause the observed surface damage, but tend to overpredict damage on the basis of the simple particle transport model used. The principal usefulness of the model in its present form is as a tool for the interpretation of the influence on fatigue life of surface damage acquired in service.

76-1934

A Theoretical Investigation of the Multileaf Journal Bearing

K.P. Oh and S.M. Rohde

Research Laboratories, General Motors Corp., Warren, MI., J. Appl. Mech., Trans. ASME, 43 (2), pp 237-242 (June 1976) 6 figs, 11 refs

Key Words: Journal bearings, Lubrication, Finite element technique

The finite-element method is used to solve the compressible Reynolds equation which governs the fluid flow between the journal surface and the leaves in a multileaf journal bearing. The solution obtained is then coupled with the load-deflection equations of the leaves to obtain such information as liftoff speed and minimum film thickness. In addition, the load-deflection equations yield the initial preload on the journal, the startup torque, the stiffness coefficients, and the equivalent damping coefficients. Such details as leaf curvature, friction between leaves, and between leaves and journal

surface are considered in the load-deflection equations. Results are obtained for a wide range of operating parameters.

BLADES

76-1935

Vibration Modes of Mistuned Bladed Disks

D.J. Ewins

Imperial College of Science & Technology, London, SW7 2BX, England, J. Engr. Power, Trans. ASME, 98 (3), pp 349-355 (July 1976) 4 figs, 6 refs

ASME Paper No. 75-GT-114

Key Words: Vibration measurement, Blades, Disks, Turbomachinery

A comprehensive experimental and theoretical investigation is reported with the object of resolving the uncertainties surrounding the effects of blade mistuning. A special experimental facility has been designed and built with which it is possible to measure bladed disk vibration under conditions of rotation and excitation which simulate closely those experienced in a turbomachine. The bladed disk testpieces have been specially designed and manufactured so that they may be very precisely tuned (or mistuned), and the whole apparatus has been designed to afford the maximum degree of control over all the relevant conditions. This paper describes a set of measurements and corresponding calculations of the many complex vibration modes possessed by a bladed disk when the blades are slightly mistuned.

76-1936

Vibration Characteristics of Composite Fan Blades and Comparison with Measured Data

C.C. Chamis

NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71893, 12 pp (1976) (presented at 17th Struct., Structural Dyn. and Mater. Conf., King of Prussia, PA., 5-7 May 76; sponsored by Am. Inst. of Aeron. and Astronautics, Am. Soc. of Mech. Engr., and Soc. of Autom. Engr.)

N76-21589

Key Words: Blades, Fans, Vibration response, Computer programs

The vibration characteristics of a composite fan blade for high-tip-speed applications were determined theoretically and the results compared with measured data. The theoretical results were obtained using a computerized capability consisting of NASTRAN coupled with composite mechanics by way of pre- and postprocessors. The predicted vibration frequencies and mode shapes were in reasonable agreement with the measured data. Theoretical results showed that different laminate configurations from the same composite system had only small effects on the blade frequency. However, the use of adhesively bonded titanium/beryllium laminar composites may improve considerably the blade vibration characteristics.

76-1937

Transonic Flow Analysis in Axial-Flow Turbomachinery Cascades by a Time-Dependent Method of Characteristics

R.A. Delaney and P. Kavanagh

Dept. of Mechanical Engineering and Engineering Research Inst., Iowa State Univ., Ames, IA., J. Engr. Power, Trans. ASME, 98 (3), pp 356-363 (July 1976) 14 figs, 8 refs

ASME Paper No. 75-GT-8

Key Words: Turbomachinery, Blades, Aerodynamic characteristics, Method of characteristics

Solutions for transonic flow in cascades are determined by a second-order time-dependent method of characteristics using bicharacteristics. The analysis method is based on unsteady, two-dimensional, compressible, inviscid flow with steady-state solutions computed as the asymptotic limit in time of transient solutions. Two turbine cascade cases are presented. The first involves subsonic flow throughout the cascade; the second involves subsonic inlet and discharge flows with transonic flow over a portion of the cascade passage. In both cases, the computed results for blade surface pressure distribution are compared with experimental data. Generally good agreement is shown.

CYLINDERS

76-1938

Vortex Shedding From a Cylinder Vibrating in Line with an Incident Uniform Flow

O.M. Griffin and S.E. Ramberg

Naval Research Laboratory, Washington, D.C., 20375 J. Fluid Mech., 75 (2), pp 257-271 (May 27, 1976) 10 figs, 20 refs

Key Words: Cylinders, Vortex shedding

A study has been made of the wake of a cylinder vibrating in line with an incident steady flow. The Reynolds number for the experiments was 190, and the vortex shedding was at all times synchronized with the vibrations of the cylinder, which were in a range of frequencies near twice the Strouhal shedding frequency for the stationary cylinder.

76-1939

Vibrations of a Row of Circular Cylinders in a Liquid
S.S. Chen

Argonne National Lab., Argonne, IL., Rept. No. ANL-CT-75-34, 41 pp (Apr 1975)

N76-22498

Key Words: Cylinders, Fluid-induced excitation, Periodic response, Harmonic excitation, Heat exchangers

The effects of interaction with surrounding liquid on the dynamic behavior of a row of circular cylinders are studied analytically. First, the hydrodynamic forces associated with cylinder motions are obtained using the potential flow theory. Then, a method of solution is presented for free vibration of a row of cylinders. Finally, steady state responses to harmonic excitations are presented. The results of the study have important application in the modeling of cross flow-induced vibration of heat exchanger tubes.

76-1940

Base Pressure of Oscillating Circular Cylinders

P.K. Stansby

Civil Engrg. Dept., Univ. of Salford, Salford, England, ASCE J. Engr. Mech. Div., 102 (EM4), pp 591-600 (Aug 1976) 6 figs, 11 refs

Key Words: Cylinders, Vortex-induced vibration

Experiments have been made to investigate the base pressure coefficients of circular cylinders oscillating transversely in a stream for a wide range of cylinder amplitudes and frequencies. This is thought to give a good indication of the variation in drag coefficient. The locking-on of vortex shedding at the cylinder frequency, associated with vortex-induced vibrations, was carefully studied. Locking-on at a third of the cylinder frequency was found to produce especially low base pressures, i.e., high drags.

DUCTS

76-1941

Design of Optimum Acoustic Treatment for Rectangular Ducts with Flow

R.E. Motsinger, R.E. Kraft and J.W. Zwick
General Electric Co., Evendale, OH., ASME Paper No. 76-GT-113

Key Words: Ducts, Rectangular bodies, Optimization, Acoustic properties, Modal analysis

A design optimization technique for acoustic treatment in rectangular ducts with uniform mean flow is presented. The technique is based on the acoustic wave solution in terms of series of characteristic duct modes. The analysis allows multiple axial treatment sections along the length of the duct and requires a known modal characterization of the sound source. Conditions of acoustic pressure and acoustic velocity continuity are used to match modal solutions at planes of impedance discontinuity in the duct. Experimental techniques for obtaining this modal characterization are presented.

76-1942

Experimental-Analytical Correlation of Optimum Duct Acoustic Liner Performance

J.D. Patterson, D.T. Sawdy and R.J. Beckemeyer
The Boeing Co., Wichita, KS., ASME Paper No. 76-GT-126

Key Words: Ducts, Rectangular bodies, Acoustic linings

Mode matching and segmented duct analytical models have been developed to take advantage of relative placement of liner segments in the design of optimal duct acoustic liners of one, two, and three segments. This paper presents experimental results which were obtained for liners installed in a rectangular duct for the case with no mean airflow through the duct. Excellent correlation is shown between the analytical and experimental data, thus verifying the analytical procedures used to design the optimum segmented lining configurations.

76-1943

Analytical and Experimental Studies of an Optimum Multisegment Phased Liner Noise Suppression Concept

D.T. Sawdy, R.J. Beckemeyer and J.D. Patterson
Boeing Co., Wichita, KS., Rept. No. NASA-CR-134960; D3-9812-1, 128 pp (May 1976)
N76-22976

Key Words: Noise reduction, Acoustic linings, Ducts, Rectangular bodies, Mathematical models

Results are presented from detailed analytical studies made to define methods for obtaining improved multisegment lining performance by taking advantage of relative placement of each lining segment. Properly phased liner segments reflect and spatially redistribute the incident acoustic energy and thus provide additional attenuation. A mathematical model was developed for rectangular ducts with uniform mean flow. Segmented acoustic fields were represented by duct eigenfunction expansions, and mode-matching was used to ensure continuity of the total field. Parametric studies were performed to identify attenuation mechanisms and define preliminary liner configurations. An optimization procedure was used to determine optimum liner impedance values for a given total lining length, Mach number, and incident modal distribution.

76-1944

Acoustic Liner Optimum Impedance for Spinning Modes with Cut-Off Ratio as the Design Criterion

E.J. Rice
NASA Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-73411; E-8741, 11 pp (1976)
N76-23943

Key Words: Acoustic linings, Acoustic impedance, Design techniques

A new acoustic liner design procedure based upon model cut-off ratio is outlined. Proposed experiments to substantiate this design procedure are outlined.

76-1945

A Theoretical and Experimental Study of the Generation and Reduction of Multiple Higher-Order Modes in a Hard-Walled, Anechoically-Terminated Cylindrical Duct

M.J. Oslac
Ph.D. Thesis, The Pennsylvania State Univ., 1975, 197 pp
UM 76-18, 388

Key Words: Ducts, Cylindrical bodies, Noise reduction, Acoustic linings

While significant strides have been made in the reduction of noise from turbomachinery, fans/compressors, and from air-moving systems in general, there is still a need for ongoing fundamental research to optimize the performance of present technology and devise new methods of noise reduction. This thesis responds to these needs by presenting a method whereby acoustic duct liners can be investigated in terms of

their optimization and by developing the fundamentals for the active noise reduction technique of phased cancellation. The optimization of acoustic duct liners can be performed by utilization of the Spinning Mode Synthesizer (SMS) originally developed at The Pennsylvania State University's Noise Control Laboratory and expanded on, in terms of its application to in-duct testing, in this thesis. The SMS is a controllable device whereby single, multiple and/or combinations of higher order duct modes can be generated and propagated in cylindrical ducts. The results presented in this thesis show excellent agreement with theoretical predictions.

PIPES AND TUBES

76-1946

Dynamic Characteristics of an Underwater Pipeline

A.R. Desai

Ph.D. Thesis, Texas A&M Univ., 1975, 114 pp
UM 76-17, 352

Key Words: Pipelines, Underwater pipelines

The current upsurge in offshore drilling for oil and gas and new deep water terminals for the supertankers has created a demand for deep water pipelines. These pipelines are being laid in deeper and more hostile waters than ever before. This study represents a novel approach with wide band random excitation being applied to the pipe model through inertial coupling. This represents an improvement over the conventional harmonic excitation applied at reduced Reynolds numbers. The analytical model results in a simple solution for the mean square response. The solution is in excellent agreement with the experimental results. Finally, two areas of further research are identified. These include the linearized model for fluid damping and the measurement of actual prototype excitation spectra.

76-1947

An Experimental Investigation of the Wall Pressure Fluctuations in Piping Containing Simple Control Devices

A.V. Karvelis

Ph.D. Thesis, The Pennsylvania State Univ., 1975,
273 pp
UM 76-18, 384

Key Words: Pipes (tubes), Sound transmission

An experimental investigation of the wall pressure field characteristics associated with several control devices is reported. The investigation was conducted using a 3.01 inch inside diameter pipe containing several control/throttling devices using air as the working fluid and operating above

critical pressure drop. Cross-correlations and narrow band spectrum levels were measured using several flush mounted wall pressure transducers located upstream and downstream of the devices. A theory is presented which relates the filtered cross covariance obtained from two wall pressure transducers to the true sound power generated by the device. This theory, which is based on the space-time correlation properties of one dimensional random acoustic fields, is verified by experiment.

PLATES AND SHELLS

76-1948

Natural Frequencies of Rectangular Flat Plates with Various Edge Conditions

Engineering Sciences Data Unit, London, England,
Rept. No. ESDU-75030, 52 pp (Nov 1975) (super-
sedes ESDU-66019)

Availability: NTIS, Attn: ESDU, Springfield, VA
N76-21584

Key Words: Rectangular plates, Natural frequencies

This report presents data in graphical form for calculating the natural frequencies of flat isotropic rectangular plates for modes up to at least (3,1) and (1,3). It covers all the 36 possible combinations of free, simply-supported and clamped edge conditions, and a method is provided to allow the estimation of natural frequencies of plates under the action of uniform biaxial in-plane loads. Each combination of edge conditions is dealt with on a single graph which presents a non-dimensional frequency coefficient which avoids either very large or very small values. The report covers any respect ratio and so allows the natural frequencies of beams to be estimated within certain stated limitations. The data are presented for the commonly used engineering materials which have a Poisson's ratio of 0.3 and guidance is provided on the effect of departure from this value in other materials. An appendix to the report provides approximate data for calculating buckling stresses under biaxial loading for plates with most of the possible combinations of edge conditions. These buckling loads are required to estimate the effect of in-plane loading on natural frequencies.

76-1949

The Flexural Vibrations of a Line-Stiffened Plate with Fluid Loading

V. Williams and F.J. Fahy

Inst. of Sound and Vibration Res., Southampton
Univ., England, Rept. No. ISVR-TR-74, 87 pp
(Feb 1975)

Sponsored by Admiralty Underwater Weapons Estab.
N76-22590

Key Words: Plates, Flexural vibrations, Fluid-induced excitation, Stiffened plates, Computer programs

Various approaches to the problem of wave propagation on a fluid loaded plate bearing stiffening beams are presented. The vibrations of an infinite fluid loaded plate bearing a finite number of parallel line stiffeners were calculated.

76-1950

Vibration and Sound Radiation of a Plate

R.J. Hannon

Ph.D. Thesis, The Pennsylvania State Univ., 1975, 117 pp

UM 76-17, 172

Key Words: Plates, Vibrating structures, Noise source identification

Because of their many vibratory resonances, plates are mechanically soft and their suspending structures have a considerable effect on their vibration and sound radiation. Experimental evaluation of acoustic properties of plates is therefore difficult. Plates of different shapes and dimensions were supported in such a way as to eliminate effects of the support on the vibration, and the velocity amplitudes due to point forces were recorded by phonograph cartridge and microphones in the near sound field.

76-1951

A Finite Element Method for the Free Vibration of Plates Allowing for Transverse Shear Deformation

T.A. Rock and E. Hinton

Dept. of Civil Engrg., Univ. of Wales, Singleton Park, Swansea SA28PP, Wales, Computers and Struc., 6 (1), pp 37-44 (Feb 1976) 4 figs, 25 refs

Key Words: Plates, Free vibration, Transverse shear deformation effects, Finite element technique

An isoparametric quadrilateral plate bending element is introduced and its use for the free vibration analysis of both thick and thin plates is examined. Plates of rectangular planform and of orthotropic materials are analyzed and excellent results are obtained. The element performance is assessed by comparison with well established analytical and numerical solutions based on Mindlin's thick plate theory, three dimensional elasticity solutions and solutions based on thin plate theory. The ease with which the element may be implemented is stressed. The use of an eigenvalue economizer which produces considerable economy in the computer solution is demonstrated. Various mass lumping schemes and numerical integration rules used in the construction of the element mass matrix are also examined.

76-1952

Mode Approximation Technique Applied to Finite Deflections of an Impulsively Loaded Viscoplastic Plate

C.T. Chon and P.S. Symonds

Dept. of Engrg., Brown Univ., Providence, RI., Rept. No. TR-1, 45 pp (Nov 1975)

AD-A024 862/5GA

Key Words: Plates, Viscoplastic properties, Sandwich structures, Modal analysis

The extension of the 'mode approximation' technique to finite deflections is illustrated in this paper by application to a fully clamped plate which is impulsively loaded and whose material exhibits rigid-perfectly plastic or viscoplastic behavior. Deflections up to about ten plate thicknesses are treated. The approximation technique requires finding 'instantaneous mode' form solutions at a sequence of times, satisfying the current equations of material behavior, edge constraint, and dynamics including finite deflections terms.

76-1953

Wave Propagation in the Linear Theory of Elastic Shells

H. Cohen

Dept. of Civil Engrg., Univ. of Manitoba, Winnipeg, Manitoba, Canada, J. Appl. Mech., Trans. ASME, 43 (2), pp 281-285 (June 1976) 8 refs

Sponsored by the National Res. Council of Canada

Key Words: Shells, Plates, Shock wave propagation, Elastic properties, Linear theories

The problem of wave propagation in elastic shells within the framework of a linear theory of a Cosserat surface is treated using the method of singular wave curves. The equations for determining the speeds of propagation and their associated wave mode shapes are obtained in a form involving the speeds of propagation in Cosserat plates and the curvature of the shell. A number of special cases in which the speeds and mode shapes simplify are considered. In particular, these special cases are shown to include as examples, certain systems of waves in elastic shells whose middle surfaces are the surface of revolution, the circular cylinder, the sphere, and the right helicoid.

76-1954

Nonlinear Vibration and Flutter of Stressed Skew Panels

P.S. Nair and S. Durvasula
Dept. of Aeron. Engrg., Indian Inst. of Science,
Bangalore, India, Rept. No. AE-331S-Rev; AE-313S,
47 pp (Oct 1975) (Supersedes AE-313S)
N76-22585

Key Words: Panels, Skew plates, Flutter

Von Karman plate equations are used to study the influence of nonlinearity on the period of vibration in unstressed and stressed skew plates. The equations of motion for flutter derived through Lagrange's equations are solved by an analog computer and also by direct numerical integration. The nature of flutter motion of buckled and unbuckled panels and the transitions from the buckled stable to flat stable configurations with increasing dynamic pressure are discussed. The influence of the aerodynamic damping term on the dynamic pressure parameter is also examined.

76-1955

On the Large-Deformation Theory of Fluid-Filled Shells of Revolution

A.E. Engin

Dept. of Engrg. Mech., The Ohio State Univ., Columbus, OH., Shock and Vibration Digest, 8 (8), pp 35-47 (Aug 1976) 3 figs, 20 refs

Key Words: Shells of revolution, Fluid filled containers

This paper is concerned with the dynamic analyses of fluid-filled shells of revolution. The shells can experience large displacements and rotations. They are membrane shells and can be subjected to general axisymmetric loads of considerable magnitude. Linear shell theory can be used only within a limited range of loading, but numerical values are in good agreement with experimental results for most engineering applications. The purpose of this paper is to develop a formulation of the theory that is applicable to biological systems composed of fluid-filled membranes, in which can occur large displacements, rotations and large elastic strains.

76-1956

Vibrations and Buckling of Axially Loaded Stiffened Cylindrical Shells with Elastic Restraints

A. Rosen and J. Singer

Dept. of Aeronautical Engrg. Technion-Israel Inst. of Technology, Haifa, Israel, Intl. J. Solids Struc., 12 (8), pp 577-588 (1976) 5 figs, 37 refs
Sponsored by the Air Force Office of Scientific Res.

Key Words: Cylindrical shells, Edge effect

A theory is derived for calculation of the influence of elastic edge restraints on the vibrations and buckling of stiffened cylindrical shells. The stiffeners are considered "smeared" and the edge restraints can be axial, radial, circumferential or rotational. Extensive computations are performed for special kinds of stringer-stiffened shells, and the theoretical predictions are compared with experimental results. A method of definition of equivalent elastically restrained boundary conditions by use of vibration tests is discussed. Application of this technique to tests on 10 shells significantly reduces the scatter in the ratio of experimental to predicted buckling loads.

RINGS

76-1957

Vibration of Heterogeneous Mechanical Systems

B. Dizioglu

Progress Repts. of VDI (Fortschritt-Berichte der VDI Zeitungen) Series 11, No. 24, 80 pp (1976)
9 figs (Summarized in VDI-Z 118 (12) June 1976)
Availability: VDI Verlag GmbH, 4 Düsseldorf 1, Postfach 1139, Germany

Key Words: Forced vibration, Free vibration, Mechanical systems, Bars

In the report free and forced vibrations of a mechanical system are examined in detail. The system consists of a bar with one end fixed and a string attached to its free end and maintained under tension in the direction of equilibrium position of the bar at its second fixed point. Special cases of the system with variable mass and density are discussed in particular detail.

STRUCTURAL

76-1958

A Survey of the Optimal Design of Vibrating Structural Elements. Part I: Theory

N. Olhoff

Dept. of Solid Mech., The Technical University of Denmark, Lyngby, Denmark, Shock and Vibration Digest, 8 (8), pp 3-10 (Aug 1976) 61 refs

Key Words: Optimum design, Structural elements, Free vibration, Variational methods

This paper surveys the optimal design of elastic structural elements undergoing free vibrations. The unified variational technique is used to minimize the material volume of a one- or two-dimensional continuous element with a specific natural frequency.

SYSTEMS

NOISE REDUCTION

(Also see Nos. 1886, 1912, 1943, 1976, 1980, 1981, 1983, 1984, 2005, 2007, 2012)

76-1959

Noise Abatement and Internal Vibrational Absorption in Potential Structural Materials

L. Kaufman, S.A. Kulin and P.P. Neshe
Manlabs, Inc., Cambridge, MA., Rept. No. AMMRC-CTR-76-3, 52 pp (Jan 1976)
AD-A022 784/3GA

Key Words: Acoustic absorption, Noise reduction, Vibration isolators

Efforts have been directed toward achieving higher yield strengths in high damping cobalt-iron base alloys by adding nickel, aluminum and manganese. Substantial increases have been achieved through aluminum and manganese additions at low levels. The range of loss factors and yield strengths which are attainable exceed currently available commercial materials. The effects of alloying additions of iron and manganese as well as reduction in grain size are being investigated as a means for reducing the brittleness of copper-aluminum-nickel alloys which exhibit thermoelastic martensitic transformations. These transformations provide high damping characteristics and high loss factors.

76-1960

Sound Attenuator for DO 27

K. Seifert
Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Zentralabteilung Luftfahrt-technik, Oberpfaffenhofen, West Germany, Rept. No. DLR-IB-555-74/4, 21 pp (July 1974)
(In German)
N76-22203

Key Words: Aircraft noise, Noise reduction, Acoustic absorption

Two sound attenuators for the engine of the relatively noisy DO 27 H and DO 27 A aircraft were constructed and tested in an anechoic chamber. The choice of a combined attenuator, consisting of a resonator and absorption part, containing a pipe lining and a muffler, is discussed. The flight noise of the DO 27 H is dealt with and the dimensions of the sound

attenuator are detailed. Measuring equipment and measuring results are discussed; it is concluded that the level of attenuation reached will probably be sufficient.

76-1961

Coupling of Helmholtz Resonators to Improve Acoustic Liners for Turbofan Engines at Low Frequency

L.W. Dean
Pratt and Whitney Aircraft, East Hartford, CT., Rept. No. NASA-CR-134912; PWA-5311, 66 pp (Aug 1975)
N76-21210

Key Words: Acoustic linings, Fans, Turbine components, Noise reduction

An analytical and test program was conducted to evaluate means for increasing the effectiveness of low frequency sound absorbing liners for aircraft turbine engines. Three schemes for coupling low frequency absorber elements were considered. These schemes were analytically modeled and their impedance was predicted over a frequency range of 50 to 1,000 Hz. The increased effectiveness of the coupled resonator concept for attenuation of low frequency broad spectrum noise is demonstrated.

76-1962

Checklists for Along-the-Path Noise Control

V. Salmon
Industrial Noise Services, Inc., 543 Bryant St., Palo Alto, CA., Noise Control Engr., 6 (2), pp 66-73 (Mar-Apr 1976) 10 refs

Key Words: Noise reduction, Industrial facilities

A series of ordered checklists concerned with control of noise along paths in gases, liquids, and solids is presented. In the lists, specific and representative problem areas, along with the appropriate noise-control techniques, materials, and devices are noted. Although the approach is chiefly in terms of industrial noise, the discussion will apply to a wide variety of problems in many fields. The lists also serve two other purposes: as a framework to which noise control engineers can add items from their own experience; and as a means of revealing gaps in the armamentarium of the engineer, where new approaches, materials, and devices are needed. The references provide a general background with the emphasis on practical applications.

76-1963

Grain Elevator Noise Control: Two Case Studies
Shiner and Associates, Skokie, IL., and Kamperman Associates, Inc., Downers Grove, IL., Illinois Inst. for Environmental Quality, Rept. No. IIEQ-76-02, 50 pp (Jan 1976)
PB-251 655/7GA

Key Words: Industrial facilities, Noise reduction

There are approximately 1,500 grain elevators in Illinois. The level of activity associated with grain elevators during the harvest season is extremely high. This seasonal noise can have a significant impact on the small towns which surround many grain elevators. These two studies identify and measure the acoustic emissions and recommend corrective actions to control the noise associated with grain elevator operations.

76-1964

Community Reaction to Noise From a Construction Site
J.B. Large and J.E. Ludlow
Inst. of Sound and Vibration Res., The Univ. of Southampton, Southampton SO9 5NH, England, Noise Control Engr., 6 (2), pp 59-65 (Mar-Apr 1976)
6 figs, 6 refs

Key Words: Noise generation, Construction industry, Human response

Reactions to noise from construction road traffic, and other sources are compared in terms of annoyance and other attitudinal factors due to exposure. The actual execution of the survey is described fully elsewhere but is described briefly here since it represents a novel and particularly economic means of gathering data on noise impact. The survey reported here was carried out around a single road construction site. The situation investigated was, by definition, a special case, since every intrusion into a residential area will be unique. Nevertheless, it is suggested that the results obtained offer some insight into the effect of construction noise on a residential community.

AIRCRAFT

(Also see Nos. 1889, 1914, 1917, 1960, 1961)

76-1965

Dynamics and Identification of Flexible Aircraft
W.R. Wells
Dept. of Aerospace Engrg., Cincinnati Univ., Cincinnati, OH., Rept. No. NASA-CR-2672, 68 pp (Apr 1976)
N76-21158

Key Words: Aircraft, Parameter identification

The equations of motion and a maximum likelihood parameter identification formulation are developed for a flexible aircraft. The various levels of approximation associated with the modal substitution representation of the elastic displacement field are discussed and illustrated when appropriate. The necessary extension of the parameter set of stability and control derivatives due to the aeroelastic effects is obtained.

76-1966

Application of Optimal Input Synthesis to Aircraft Parameter Identification
N.K. Gupta, R.K. Mehra and W.E. Hall, Jr.
Systems Control, Inc., Palo Alto, CA., J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 139-145 (June 1976) 6 figs, 13 refs
Sponsored by NASA and Office of Naval Research

Key Words: Aircraft, Parameter identification, Structural synthesis, Frequency domain

This paper considers an application of the Frequency Domain Input Synthesis procedure for identifying the stability and control derivatives of an aircraft. In previous studies, the input design has mostly been carried out in the time-domain. However, by using a frequency-domain approach, criteria that are not easily handled by the time-domain approaches are utilized. Numerical results are presented for optimal elevator deflections to estimate the longitudinal stability and control derivatives subject to root-mean square constraints on the input. The applicability of the steady state optimal inputs to finite duration flight testing is reported.

76-1967

Aerodynamic Symmetry of Aircraft and Guided Missiles
P.H. Zipfel
Air Force Armament Lab., Eglin Air Force Base, FL., J. Aircraft, 13 (7), pp 470-475 (July 1976) 2 figs, 5 refs

Key Words: Aircraft, Missiles, Mathematical modeling

A technique is developed that takes advantage of the inherent configurational symmetries of aircraft and guided missiles to eliminate some force and moment derivatives. Starting with the Principle of Material Indifference, tensor analysis is employed to derive two simple conditions for vanishing aerodynamic derivatives. The results apply to derivatives of arbitrary order, taken with respect to linear and angular velocities, linear accelerations, and control surface deflections. Two charts are presented that sift out the vanishing derivatives up to second order for missiles with tetragonal symmetry, and up to third order for aircraft with reflectional symmetry.

76-1968

Dynamic Analysis of Aircraft Impact Using the Linear Elastic Finite Element Codes FINEL, SAP, and STARDYNE

P. Lundsager and S. Krenk

Danish Atomic Energy Commission, Riscoe, Rept. No. RISO-M-1817, 18 pp (Aug 28, 1975)
N76-21596

Key Words: Aircraft, Impact response, Computer programs

The static and dynamic response of a cylindrical/spherical containment to a Boeing 720 impact was computed using 3 different linear elastic computer codes. Stress and displacement fields are shown together with time histories for a point in the impact zone.

76-1969

Repetitive Flutter Calculations in Structural Design

R.T. Haftka and E.C. Yates, Jr.

Ill. Inst. of Technology, Chicago, IL., J. Aircraft, 13 (7), pp 454-461 (July 1976) 8 figs, 18 refs
Sponsored by NASA

Key Words: Aircraft vibration, Flutter

Some aspects of efficient modal flutter analysis are investigated for use in aircraft structural design which may involve many iterations. Expressions for the generalized aerodynamic forces are derived which are separated into mode-dependent and mode-independent parts; this permits rapid recalculation of the forces when the modes are changed. The computer times required for the various parts of a single flutter analysis are presented for some example problems. These examples are used to compare the efficiency of using periodically updated natural vibration modes fixed modes with resizing methods that do not require the derivatives of any of the flutter parameters with respect to structural variables. The main computational penalty in updating modes is found to be in the recalculation of the modes, rather than in the calculation of the generalized aerodynamic forces. Flutter calculations also are examined for resizing methods that do require the derivatives of the flutter frequency, flutter speed, or flutter altitude with respect to design variables. The convergence of such derivatives with increasing number of modes is investigated with the aid of two examples. The poor convergence of the derivatives precluded comparison of the use of continually updated vs fixed modes for resizing methods that require such derivatives.

76-1970

Flutter of Asymmetrically Swept Wings

T.A. Weisshaar and J.B. Crittenden

Dept. of Aerospace and Ocean Engrg., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA., Rept. No. NASA-CR-146815, 32 pp (Mar 12, 1976) (Backup document for AIAA Synoptic scheduled for publication in AIAA Journal in Aug. 1976)
N76-21164

Key Words: Aircraft wings, Flutter

Two formulations of the oblique wing flutter problem are presented; one formulation allows only simple wing bending deformations and rigid body roll as degrees of freedom, while the second formulation includes a more complex bending-torsional deformation together with the roll freedom. Flutter is found to occur in two basic modes. The first mode is associated with wing bending-aircraft roll coupling and occurs at low values of reduced frequency. The second instability mode closely resembles a classical bending-torsion wing flutter event. This latter mode occurs at much higher reduced frequencies than the first. The occurrence of the bending-roll coupling mode is shown to lead to lower flutter speeds while the bending-torsion mode is associated with higher flutter speeds. The ratio of the wing mass moment of inertia in roll to the fuselage roll moment of inertia is found to be a major factor in the determination of which of the two instabilities is critical.

76-1971

Technical Evaluation Report of AGARD Specialists Meeting on Wing-with-Stores Flutter

W.J. Mykytow

AGARD, Paris, France, Rept. No. AGARD-AR-96; ISBN-92-835-1209-X, 13 pp (Feb 1976) (Meeting held at Munich, 9 Oct 1974 during 39th Meeting of Struct. and Mater. Panel)
N76-21163

Key Words: Aircraft wings, Wing stores, Flutter

The carriage of stores on wings significantly changes their dynamic characteristics and often adversely affects their flutter properties as a result of reduced wing frequencies and the introduction of critical frequency ratios together with inertia, elastic and aerodynamic coupling between loads. Adverse flutter characteristics and significantly lowered flutter speeds occur and these restrictions severely constrain the speed - altitude performance envelope that can be achieved by an aircraft. The variety of stores that can be carried on modern tactical airplanes generates a need to accurately evaluate the literally thousands of possible store combinations which can be carried by such aircraft. Results are presented from a conference on information and procedures in use in the various NATO nations to solve the flutter problems associated with the carriage of external stores on wings. Nine presentations were given and are summarized. Recommendations concerning possible future efforts on the subject are given.

76-1972

Comparison of Supercritical and Conventional Wing Flutter Characteristics

M.G. Farmer, P.W. Hanson and E.C. Wynne
NASA, Langley Res. Ctr., Langley Station, VA.,
Rept. No. NASA-TM-X-72837, 9 pp (May 1976)
N76-22159

Key Words: Aircraft wings, Flutter, Wind tunnel test

A wind-tunnel study was undertaken to directly compare the measured flutter boundaries of two dynamically similar aeroelastic models which had the same planform, maximum thickness-to-chord ratio, and as nearly identical stiffness and mass distributions as possible, with one wing having a supercritical airfoil and the other a conventional airfoil. The considerations and problems associated with flutter testing supercritical wing models at or near design lift coefficients are discussed, and the measured transonic boundaries of the two wings are compared with boundaries calculated with a subsonic lifting surface theory.

76-1973

Comments on Measuring Techniques for Unsteady Derivatives

J.W.G. VanNunen
Fluid Dynamics Div., National Aerospace Lab.,
Amsterdam, Netherlands, Rept. No. NLR-MP-75020-U, 8 pp (May 1975)
N76-22171

Key Words: Aircraft, Free vibration, Forced vibration

Some experimental methods applied at present to the measurements of unsteady derivatives are reviewed. They include the forced oscillation and free oscillation methods partly focused on the analysis of overall loads and moments acting on oscillating aircraft models. Further attention is paid to the measurement of unsteady pressure distribution as an alternative procedure to get information about derivatives; this technique is hardly to be considered as a substitute to the previous method, but may be suitable in the development and validation of analytical prediction methods.

76-1974

Responses of Small Rigid Aircraft to Discrete and Continuous Gust Analysis. Phase 1. Final Report. Nov 1972 - Nov 1974

J. Petrakis and N. Miller
National Aviation Facilities Experimental Ctr.,
Atlantic City, NJ., Rept. No. AD-A020103/8; FAA-RD-74-160; FAA-NA-74-44, 121 pp (Dec 1975)
N76-21191

Key Words: Aircraft, Wind-induced excitation, Computer programs

An evaluation is made of methods developed for estimating longitudinal and lateral rigid-body responses of airplanes to random atmospheric turbulence. A computer program, evolved from this study, calculates general aviation aircraft stability derivatives from known geometric properties used as inputs for the calculation of aircraft response (also a developed part of the computer program). It was found that the two degrees-of-freedom rigid-body power spectral density analysis produced lower normal load factor responses than a similar single degree-of-freedom analysis for aircraft of gross weight from 3,000 to 17,500 pounds. Also to produce an equivalent discrete load factor for the two degrees-of-freedom analysis, a higher spectral velocity value must be used compared to that of the single degree-of-freedom approach.

76-1975

Introduction to a Fighter Aircraft Loading Standard for Fatigue Evaluation (Falstaff)

G.M. VanDijk and J.B. DeJonge
Structures and Materials Div., National Aerospace Lab., Amsterdam, Netherlands, Rept. No. NLR-MP-75017-U, 40 pp (May 1975)
N76-22598

Key Words: Aircraft, Fatigue life, Standards

Falstaff (Fighter Aircraft Loading Standard for Fatigue Evaluation), a loading history standard pertaining to fighter aircraft wing bending primarily governed by maneuver loadings, is derived in order to evaluate the fatigue performance of structural materials and components and to establish fatigue design charts. The present report concerns a joint international development effort involving Dutch, German, and Swiss institutes. Details are presented with regard to the general development philosophy and data sources considered. The development procedures followed are summarized. The results of some preliminary validation tests are reported.

76-1976

Experimental Evaluation of NAS Miramar Hush House (Project P-114) Volume 1

W.P. Sule and E.T. Pulcher
Ground Support Equipment Dept., Naval Air Engineering Center, Lakehurst, NJ., Rept. No. NAEC-GSED-96-Vol-1, 147 pp (Feb 1976) (See also Vol 2, AD-A024 404)
AD-A024 403/8GA

Key Words: Aircraft noise, Noise reduction, Model testing, Test facilities

This report summarizes the results of an extensive experimental test and evaluation of the new NAS Miramar Hush House. The tests consisted of both aero-thermodynamic and acoustic data acquisition. Four different aircraft (A-4, F-8, F-4, F-14) were run in the facility and acoustic data was obtained on two of the aircraft (F-4, F-14). The results of the full size testing were compared with 1/15th scale model tests results to estimate the reliability of scale model tests for this application.

76-1977

Sources and Characteristics of Interior Noise in General Aviation Aircraft

J.J. Catherines and S.K. Jha

Cranfield Inst. of Technology, England, Rept. No. NASA-TM-X-72839, 24 pp (Apr 1976) (presented at 91st Meeting Acoust. Soc. Am., Washington, D.C., 5-9 Apr 1976)
N76-21990

Key Words: Aircraft noise, Noise source identification, Sound transmission, Acoustic tests

A field study was conducted to examine the interior noise characteristics of a general aviation aircraft. The goals were to identify the major noise sources and their relative contribution and to establish the noise transmission paths and their relative importance. Tests were performed on an aircraft operating under stationary conditions on the ground. Results show that the interior noise level of light aircraft is dominated by broadband, low frequencies (below 1,000 Hz). Both the propeller and the engine are dominant sources, however, the contribution from the propeller is significantly more than the engine at its fundamental blade passage frequency. The data suggest that the airborne path is more dominant than the structure-borne path in the transmission of broadband, low frequency noise which apparently results from the exhaust.

76-1978

Noise Level Measurements in Cockpits and Cabins of DFVLR, Oberpfaffenhofen Flight Unit Aircraft (Results of a First Series of Measurements)

H. Galleithner

Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Zentralabteilung Luftfahrt-technik, Oberpfaffenhofen, West Germany, Rept. No. DLR-IB-555-74/11, 20 pp (Dec 1974)
(In German)
N76-22204

Key Words: Aircraft noise, Noise measurement

The noise, at car level, of Dornier DO 27 and 28, Beech 65, Piaggio Pi 149 D and Cessna 207 aircraft was measured during typical flight phases on the runway, during takeoff, and during cruising. Results were tabulated. It is shown that the noise level of the different aircrafts can be classified, transforming the dB (A)-level into a dimensionless characteristic performance number, which is a measure for the effective engine performance as a percentage of the continuous performance.

76-1979

Establishing Noise Criteria for Residential Living in Areas Surrounding Commercial Aviation Airports

MAN-Acoustics and Noise, Inc., Seattle, WA., Rept. No. AD-A021683/8; MAN-1011/FAA-RD-75-211, 68 pp (Nov 1975)

N76-23946

Key Words: Aircraft noise, Airports, Human response

Four different airport noise conditions were simulated. Three conditions involved day flights of 150 aircraft with average Noise Exposure Forecast (NEF) values of 36.9, 32.5, and 26.9. The fourth condition added 18 night flights which resulted in a mean NEF of 32.9. Interference with daily living activities and annoyance responses to the four conditions were obtained.

76-1980

Noise Reduction as Affected by the Extent and Distribution of Acoustic Treatment in a Turbofan Engine Inlet

G.L. Minner and L. Homyak

NASA, Lewis Res. Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71904; E-8693, 18 pp (1976)
N76-23268

Key Words: Engine noise, Noise reduction

An inlet noise suppressor for a TF-34 engine designed to have three acoustically treated rings was tested with several different ring arrangements. The configurations included: all three rings; two outer rings; single outer ring; single intermediate ring, and finally no rings. It was expected that as rings were removed, the acoustic performance would be degraded considerably. While a degradation occurred, it was not as large as predictions indicated. The prediction showed good agreement with the data only for the full-ring inlet configuration.

76-1981

Effects of Perforated Flap Surfaces and Screens on Acoustics of a Large Externally Blown Flap Model

R.J. Burns, D.J. McKinzie, Jr. and J.M. Wagner
NASA, Lewis Res. Ctr., Cleveland, OH., Rept. No. NASA-TM-X3335; E8559, 41 pp (Apr 1976)
N76-22156

Key Words: Aircraft noise, Noise reduction

Various model geometries and combinations of perforated flap surfaces and screens mounted close to the flap surfaces were studied for application to jet-flap noise attenuation for externally blown flap, under-the-wing aircraft. The efforts to reduce jet-flap interaction noise were marginally successful. Maximum attenuations of less than 4 db in overall sound pressure level were obtained in the flyover plane. Noise reductions obtained in the low-to-middle-frequency ranges (up to 7 db) were generally offset by large increases in high-frequency noise (up to 20 db).

76-1982

Status Report - Subsonic Aircraft Noise Reduction

J.W. Little and R.E. Russell
Boeing Commercial Airplane Co., Seattle, WA.,
ASME Paper No. 76-GT-116

Key Words: Aircraft noise, Noise reduction

The design process for a subsonic commercial transport aircraft is discussed with emphasis on noise considerations. A review of the process for identifying component noise levels is followed by a description of the design for noise reduction of typical components. A discussion of system constraints in the practical application of noise-reduction concepts is followed by comments on the need to include a reasonable design tolerance. Some aspects of the tradeoff between noise reduction and performance are described. Finally, a projection is made of future projected noise reductions based on yet-to-be-accomplished research programs.

76-1983

Noise Reduction Tests of Large-Scale-Model Externally Blown Flap Using Trailing-Edge Blowing and Partial Flap Slot Covering

D.J. McKinzie, Jr., R.J. Burns and J.M. Wagner
NASA, Lewis Res. Ctr., Cleveland, OH., Rept. No. NASA-TM-X-3379, E-8598, 65 pp (Apr 1976)
N76-22977

Key Words: Aircraft noise, Noise reduction

Noise data were obtained with a large-scale cold-flow model of a two-flap, under-the-wing, externally blown flap proposed for use on future STOL aircraft. The noise suppression effectiveness of locating a slot conical nozzle at the trailing edge of the second flap and of applying partial covers to the slots between the wing and flaps was evaluated. Overall-sound-pressure-level reductions of 5 db occurred below the wing in the flyover plane. Existing models of several noise sources were applied to the test results. The resulting analytical relation compares favorably with the test data. The noise source mechanisms were analyzed and are discussed.

76-1984

Phase 2 Program on Ground Test of Refanned JT8D Turbofan Engines and Nacelles for the 727 Airplane. Volume 3: Ground Tests. Final Report

Boeing Commercial Airplane Co., Seattle, WA., Rept. No. NASA-CR-134799; D6-42440-3-Vol-3, 350 pp (Dec 1975)
N76-21189

Key Words: Aircraft engines, Acoustic tests, Noise reduction

The NASA Refan Program included full-scale performance and noise ground tests of both a current production (JT8D-15) and a refanned (JT8D-115) engine. A description of the two ground tests including detailed propulsion, noise, and structural test results is presented. The primary objectives of the total test program were comparison of JT8D-15 and JT8D-115 overall propulsion system performance and noise characteristics and determination of incremental component noise levels. Other objectives of the test program included: (1) determination of acoustic treatment effectiveness; (2) measurement of internal sound pressure levels; (3) measurement of inlet and exhaust hardware performance; (4) determination of center-engine surge margin; and (5) evaluation of certain structural characteristics associated with the 727 refan center-engine inlet duct and JT8D refan engine exhaust system. The JT8D-15 and -115 tests were conducted during September 1974 and January to March 1975, respectively.

76-1985

Small Scale Noise and Wind Tunnel Tests of Upper Surface Blowing Nozzle Flap Concepts. Volume 1. Aerodynamic Test Results

D.J. Renselaer, R.S. Nishida and C.A. Wilkin
Aircraft Div., Rockwell International Corp., Los Angeles, CA., Rept. No. NASA-CR-137747, 143 pp (Dec 1975)
N76-21159

Key Words: Aircraft, Propulsion systems, Wind tunnel tests, Acoustic tests

The results and analyses of aerodynamic and acoustic studies conducted on the small scale noise and wind tunnel tests of upper surface blowing nozzle flap concepts are presented. Various types of nozzle flap concepts were tested. These are an upper surface blowing concept with a multiple slot arrangement with seven slots (seven slotted nozzle), an upper surface blowing type with a large nozzle exit at approximately mid-chord location in conjunction with a powered trailing edge flap with multiple slots (split flow or partially slotted nozzle). In addition, aerodynamic tests were continued on a similar multi-slotted nozzle flap, but with 14 slots. All three types of nozzle flap concepts tested appear to be about equal in overall aerodynamic performance but with the split flow nozzle somewhat better than the other two nozzle flaps in the landing approach mode.

76-1986

Small Scale Noise and Wind Tunnel Tests of Upper Surface Blowing Nozzle Flap Concepts. Volume 2. Acoustic Test Results

Y. Kadman

Rockwell International Corp., Los Angeles, CA., Rept. No. NASA-CR-137748; BBN-3130, 100 pp (Jan 1976) (prepared by Bolt Beranek and Newman, Inc., Cambridge, MA)
N76-21160

Key Words: Aircraft, Propulsion systems, Wind tunnel tests, Acoustic tests

Results are summarized of acoustic tests on two advanced concepts of upper-surface-blowing propulsive lift devices.

BIOENGINEERING

(See No. 1955)

BRIDGES

(Also see No. 1930)

76-1987

The Performance of Lapped Splices Under Rapid Loading

T. Rezanoff, M.P. Bufkin, J.O. Jirsa and J.E. Breen
Center for Highway Research, Texas Univ. at Austin, Austin, TX., Rept. No. CFHR-3-5-72-154-2, FHWA/RD-76-S0457, 108 pp (Jan 1975) (prepared in cooperation with Texas Highway Dept., Austin, TX)
PB-251 973/4GA

Key Words: Dynamic response, Bridges (structures), Reinforced concrete, Finite difference theory

The impact or dynamic response and resistance of structures or structural components has been of increasing interest in recent years. The failures of lapped splices at the bases of some concrete highway support structures during the San Fernando earthquake led to questions as to the suitability and adequacy of a lapped splice subjected to fast loading rates. In addition, the damage produced by hurricanes and tornadoes surpasses earthquake damage and gives added impetus to the study of structural behavior under dynamic loads. In this investigation the behavior of lapped splices subjected to impact loading was studied. The objective was to compare the strength and behavior of splices under static and dynamic loads and to determine whether the design provisions based primarily on static tests could be relied on under dynamic loading conditions.

76-1988

Binary Flutter of Suspension Bridge Deck

Y. Nakamura and T. Yoshimura

Res. Inst. for Applied Mech., Kyushu University, Fukuoka, Japan, ASCE J. Engr. Mech. Div., 102 (EM4), pp 685-700 (Aug 1976) 7 figs, 12 refs

Key Words: Suspension bridges, Flutter, Wind tunnel tests

Wind tunnel experiments on models of suspension bridge deck sections with plate girders of various heights are made to show that binary flutter of suspension bridge deck sections can be classified into three types which have different mechanisms of excitation; i.e., the classical type flutter, the single-degree-of-freedom type, and the intermediate type. Analyses on an energy equation of bluff structures with many degrees-of-freedom are also given to establish the theoretical basis of the classification of binary flutter. Although the geometry of the deck section is found to be the most dominant parameter that influences the type of flutter, it may also depend on various other parameters. The uncoupled frequency ratio is chosen, among others, and its effects on the three types of binary flutter are investigated.

BUILDING

76-1989

Investigation of Wind Damage in the Metropolitan Washington, D.C. Area, April 3-4, 1975

F.Y. Yokel, C.W. Yancey, L.E. Cattaneo and R.D. Marshall

National Bureau of Standards, Washington, D.C., Rept. No. NBS-TN-909, 68 pp (May 1976)
Sponsored in part by Defense Civil Preparedness Agency, Washington, D.C.
PB-252 681/2GA

Key Words: Buildings, Wind-induced excitation

A limited investigation was conducted of wind damage that occurred on April 3 and 4, 1975 in the Metropolitan Washington, D.C. area. Meteorological data indicate that the winds were somewhat less severe than those that should be anticipated by designers. Thus, most of the observed damage reflects inadequacies in design or construction. Damage was observed in occupied buildings, as well as in buildings under construction. Damaged elements of occupied buildings included: Masonry curtain walls; masonry gable walls; masonry veneer; roofs with overhangs; roofing; and cladding. Damaged elements of buildings under construction included roofs and masonry walls.

76-1990

Analysis and Design of Tube-Type Tall Building Structures

H. deClercq and G.H. Powell

Earthquake Engrg. Res. Ctr., California University, Berkeley, CA., Rept. No. EERC-76-5, 210 pp (Feb 1976)

PB-252 220/9GA

Key Words: Multistory buildings, Automated design, Macroelement method, Joints (junctions)

Tube-type structures for tall buildings generally consist of large numbers of members connected at an equally large number of joints. This causes the 'exact' analysis of such structures to be expensive, and manual sizing of members during design to be tedious. In this report a method, called the 'Macroelement Method,' is presented for the approximate analysis of three-dimensional tube-type frames consisting of horizontal beams and vertical columns connected at rigid joints. A linear elastic three dimensional analysis can be performed very economically by this method for buildings of arbitrary plan, including such structures as bundled tube frames. The macroelement method is a variation of the finite element method, in which a single element embraces a rectangular portion of frame consisting of several columns and several beams. Elements are connected at a small number of nodes. Shape functions are assumed over the region of each element to express the displacements of the beam-column joints in terms of the displacements of the nodes.

76-1991

Influence of Canyon on Soil-Structure Interaction

H.L. Wong, M.D. Trifunac and K.K. Lo

California Inst. of Tech., Pasadena, CA., ASCE J. Engr. Mech. Div., 102 (EM4), pp 671-684 (Aug 1976) 5 figs, 14 refs

Key Words: Interaction: soil-structure, Seismic design, Buildings, Secondary waves

The exact solution of the dynamic response of a shear wall on an elastic half space with a canyon having semicircular cross section is presented for excitation by plane SH-waves. It is shown that the driving forces and compliances in the soil-structure interaction problem depend directly on the existence of a canyon. For different angles of incident SH-waves the existence of a canyon may shield or amplify the building motions for the waves whose wavelengths are short compared to the canyon dimensions. In most cases building motions are smaller when the building is located behind the canyon with respect to incident waves. However, these motions may be amplified when the building is placed in front of the canyon. The results of this analysis suggest that the shielding of building foundations by canyons or trenches may not be very useful from the practical engineering point of view.

76-1992

Structural Damage Caused by the 1976 Guatemala Earthquake

M.A. Sozen and J. Roesset

Dept. of Civ. Engrg., Illinois Univ. at Urbana-Champaign, IL., Rept. No. UILV-ENG-76-2003, 87 pp (Mar 1976)

PB-252 350/4GA

Key Words: Earthquake damage

This report contains a preliminary description of the response of engineered construction in Guatemala City to the earthquakes of 4 and 6 February 1976. The technical information contained in the report is limited primarily to photographic evidence. No quantitative analysis is included. It is believed that an early release of the available information will be of value to emphasize some of the structural phenomena which do not need analysis and to put into perspective the level of damage experienced in the city.

CONSTRUCTION

(See No. 1964)

HELICOPTERS

(Also see No. 2018)

76-1993

Energy-Absorbing Materials for Improving Helicopter Crashworthiness

C.E. Kimball and R.C. DeHart
Southwest Research Inst., San Antonio, TX., 27 pp
(Mar 1976)
AD-A023 006/OGA

Key Words: Helicopters, Energy absorption, Honeycomb, Foams, Collision research (aircraft)

The purpose of the program was to identify materials which were not only suitable for structural components but were capable of absorbing energy at acceptable deceleration levels in a crash environment. After review of available materials for their energy absorption capability, five candidate materials were selected and a test program initiated to demonstrate their attenuation properties. Those selected were three types of honeycomb, a rigid foam, and a flexible foam.

HUMAN

(Also see No. 1964)

76-1994

Dynamic Response of Intervertebral Joints of a Seated Farm Machine Operator in the Range 5-50 Hz
O.A. Braunbeck
Ph.D. Thesis, Michigan State Univ., 1976, 158 pp
UM 76-18, 600

Key Words: Agricultural machinery, Vibration excitation, Human response, Mathematical models

An hypothesis is proposed in this work which suggests that if intervertebral joint deformations present distinct levels at frequencies encountered in the seat of farm machinery, they will create a fatigue type loading of the intervertebral joint sufficient to induce pain sensations. A lumped parameter dynamic model of the upper torso and head is proposed, whose main objective is to predict lumbar intervertebral joint deformations. The governing differential equations of motion are written for a linear system exposed to sinusoidal small amplitude displacement excitation in the vertical direction through the pelvis. A particular solution is found for the system of 58 second order differential equations that provides an equal number of complex amplitudes of motion, corresponding to each one of the degrees of freedom in the system. The rheological behavior of deformable components of the structure is modeled by means of Kelvin viscoelastic elements. The stiffness and damping coefficients for the axial mode of oscillation are derived from impedance data taken from isolated vertebral units. The model is validated by computing seat to head transmissibility as well as driving point impedance coefficients over the frequency range 5-50 Hz. The transmissibility and impedance curves corresponding to the model closely resemble the experimental curves even though the values differ somewhat.

76-1995

Correlation of Floor Vibration to Human Response
J.R. Shaver
Ctr. for Bldg. Tech., National Bureau of Standards, Washington, D.C., Rept. No. NBS-TN-904, 31 pp
(May 1976) (Supersedes Rept. No. NBSIR-75-951, PB-249-094)
Sponsored in part by Dept. of Housing and Urban Dev., Washington, D.C.
PB-253 230/7GA

Key Words: Floors, Vibration excitation, Human response

A new approach to the problem of perceptible floor vibrations is presented predicated on the realization that human activity and human response to this activity are random variables. Techniques for data reduction are discussed, and a detailed description of one approach is given along with the associated computer program. Data from floor vibrations are compared with current criteria for human response to vibration.

ISOLATION

(Also see Nos. 1959, 2017)

76-1996

Oil Compressibility and Polytropic Air Compression Analysis for Oleopneumatic Shock Struts
M.K. Wahi
Boeing Commercial Airplane Co., Renton, WA., J. Aircraft, 13 (7), pp 527-530 (July 1976) 6 figs, 7 refs

Key Words: Shock absorbers, Mathematical models

Various aspects of dynamic design of oleopneumatic landing gear shock absorbers were investigated. A review of available literature shows that effects on shock absorption characteristics due to hydraulic fluid compressibility, gas solubility and its entrainment-in-oil, and the nature of polytropic exponent during the compression stroke are often neglected by the designer. An attempt has been made to establish the importance of these parameters and possible means of representing them as mathematical models. The suggested models are capable of being incorporated into any realistic shock strut dynamics simulation.

76-1997

Translatory Shock Absorber for Attitude Sensors
G.L. VonPragenau, I.T. Morgan, Jr. and C.A. Kirby
NASA, Marshall Space Flight Ctr., Huntsville, AL., U.S. Patent 3,952,980, 5 pp (Apr 27, 1976)
N76-22284

Key Words: Shock absorbers, Spacecraft equipment, Attitude control equipment

A translatory shock absorber is provided for mounting an attitude sensor thereon for isolating a sensor from translatory vibrations. The translatory shock absorber includes a hollow block structure formed as one piece to form a parallelogram. The absorber block structure includes a movable top plate for supporting the attitude sensor and a fixed base plate with opposed side plates interposed between. At the junctions of the side plates, and the base and top plates, there are provided grooves which act as flexible hinges for attenuating translatory vibrations. A damping material is supported on a pedestal which is carried on the base plate between the side plates thereof. The top of the damping material rests against the bottom surface of the top plate for eliminating the resonant peaks of vibration.

MATERIAL HANDLING

(See No. 1963)

MECHANICAL

76-1998

Diesel-Powered Heavy-Duty Refrigeration Unit Noise

J.T. Retka

Corad Div., Donaldson Co., Inc., Minneapolis, MN.,
Rept. No. DOT-TSC-OST-75-53, 50 pp (Jan 1976)
PB-250 554

Key Words: Refrigerators, Noise measurement

A series of noise measurements were made on a diesel-powered heavy-duty refrigeration unit. Noise survey information collected included: polar plots of the 'A Weighted' noise levels of the unit under maximum and minimum load conditions; a linear and 'A' weighted acoustical time history of the refrigeration unit noise operating from start-up to load conditions representing both minimum (unloaded) and maximum (loaded) cooling capacity; the determination of the unmuffled refrigeration unit engine exhaust noise level under maximum and minimum load conditions; the determination of the noise contribution, under maximum load conditions, from the refrigeration unit engine exhaust and engine cooling system fan to the overall system noise.

METAL WORKING AND FORMING

76-1999

Identification and Analysis of Machine Tool System Dynamics under Actual Working Conditions Using Time Series Methods

F.A. Burney

Ph.D. Thesis, The University of Wisconsin-Madison,
1976, 221 pp
UM 76-15, 981

Key Words: Machine tools, Chatter, Series (mathematics), Mathematical models

The identification and analysis of a machine tool system dynamics under actual working conditions is useful for the purpose of the machine tool chatter control, acceptance testing, and design evaluation. On account of the stochastic and time-dependent nature of the machine tool vibrations, this thesis utilizes a new time series technique called the 'Dynamic Data System (DDS)' for the purpose of such an analysis. Described succinctly, the technique develops a statistically adequate mathematical model of the system under a given condition from the data collected from the system. The data collection, which has to be based on a proper physical understanding of the system, can be performed during the course of its (system's) normal operation. Considerable experimental work is done in this research to monitor and record the cutter-workpiece relative vibration and the cutting force data from a vertical milling machine during the face-milling operations carried out under different cutting conditions. A new type of force transducer is employed for collecting the tangential cutting force signal.

76-2000

Kinetic and Dynamic Effects on the Upper-Bound Loads in Metal-Forming Processes

J. Tirosh and S. Kobayashi

Dept. of Mechanical Engrg., Material Processing and Machine Tool Ctr., Technion-Israel Inst. of Tech., Haifa, Israel, J. Appl. Mech., Trans. ASME, 43 (2), pp 314-318 (June 1976) 4 figs, 14 refs
ASME Paper No. 76-APM-28

Key Words: Metal working

The regular upper-bound approach in metal-forming processes is extended to time-dependent processes. The ultimate goal is to estimate, in an approximate manner, time rate effects such as machine speed and material inertia, on the forming load of time independent materials. The admissible velocity field with associated jumps is used to generate an acceleration flow field and associated flow resistance.

PACKAGE

76-2001

Shock and Vibration Evaluation of ML-8094/199 Tube Container

R.V. Brown

Air Force Packaging Evaluation Agency, Wright-Patterson AFB, OH., Rept. No. DSPT-76-16, 22 pp (May 1976)
AD-A025 147/0GA

Key Words: Shipping containers, Packaging, Vibration tests, Shock tests, Drop tests

The Defense Electronic supply Center reported that excessive damage had been experienced during shipment of ML-8094/199 High Voltage Rectifier tubes from the Connecticut based manufacturer to Peterson Field, Colorado. The main objectives of this study were twofold: (1) Determine if the present pack will protect the tube when subjected to rough handling tests as prescribed by MIL-P-116; and (2) Determine if the pack could be modified to afford increased protection to the tube.

76-2002

Variability of Cushioning Properties of Polyurethane Foams

R.V. Brown

Air Force Packaging Evaluation Agency, Wright-Patterson AFB, OH., Rept. No. DSPT-76-8, 18 pp (Mar 1976)
AD-A022 461/8GA

Key Words: Packaging materials, Polyurethane resins, Foams

The primary objective of this study was to determine the variability in the dynamic cushioning properties of flexible polyurethane foam materials procured from different sources under the requirements of MIL-P-0026514C. A secondary objective was to establish the degree of correlation between the dynamic cushioning properties of polyurethane foam and various material physical properties such as density, static stress characteristics and Indent Load Deflection (ILD) factor. The results of this study show that there is considerable variability in the dynamic cushioning properties of polyurethane foam materials.

PUMPS, TURBINES, FANS, COMPRESSORS

(Also see Nos. 1936, 1961, 1984)

76-2003

Determination and Probabilistic Foundation Forces Resulting from an Unbalanced Turbine

M.L. Boyce and T.J. Kozik

Texas A & M Univ., College Station, TX., ASME Paper No. 76-GT-120

Key Words: Turbines, Machine foundations

This paper considers the problem of the unbalanced rotating turbine as a single degree of freedom system, wherein the principal mode of vibration is a translation in the direction of the machine supports. The distance from the center of mass of the rotating mass to the geometric axis, also known as the effective eccentricity, is modeled as a random variable. The expression for the root mean square response of the rotating machine is derived and related to the statistical analog for the deterministic expression for the foundation force. These results are numerically compared to their equivalent deterministic values.

76-2004

Modal Structure Inferred from Static Far-Field Noise Directivity

A.V. Saule

NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71909; E-8704, 12 pp (1976) (proposed for presentation at 3d Aero-Acoustics Conf., Palo Alto, CA., 20-23 July 1976; sponsored by AIAA)
N76-21207

Key Words: Fans, Turbine components, Noise generation

Turbofan noise directivity calculated for two directivity models was compared with experimental, blade passing frequency data from two fans at 60 and 90 percent speeds. Experimental data indicated similar directivity patterns which were well represented by a single average data curve. Calculated points using the equal amplitude model showed over-prediction near the fan axis and near the 90 degree position.

76-2005

Noise Reduction From the Redesign of a Fan Stage to Minimize Stator Lift Fluctuations

J.H. Dittmar and R.P. Woodward

NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71896; E-8682, 10 pp (1976) (proposed for presentation at 3d Aero-Acoustics Conf., Palo Alto, CA., 20-23 July 1976; sponsored by AIAA)
N76-21206

Key Words: Fans, Noise reduction

An existing fan stage, redesigned to reduce stator lift fluctuations, was acoustically tested for reduced noise generation. The lift fluctuations on the stator were reduced by increasing the stator chord, adjusting incidence angles, and by adjusting the rotor velocity diagrams.

76-2006

Noise Comparisons of Single and Two Stage Demonstrator Fans for Advanced Technology Aircraft

M.F. Heidmann

NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-71899; E-8688, 18 pp (1976) N76-23265

Key Words: Fans, Noise reduction

A high-speed single-stage and a low-speed two-stage fan were designed, fabricated, and tested to demonstrate their predicted low noise performance for an advanced 0.85-0.90 cruise Mach number aircraft requiring a 1.8-1.9 pressure ratio fan. Acoustic tests were made with both unsuppressed and suppressed configurations. The two-stage fan demonstrated that quiet fan technology developed for low-speed single-stage fan is applicable to two-stage designs. The unsuppressed high-speed single-stage fan demonstrated that significant reductions in inlet noise can be achieved from the sonic blockage caused by supersonic flow in the rotor blading

76-2007

Altitude Performance of a Low-Noise-Technology Fan in a Turbofan Engine With and Without a Sound Suppressing Nacelle

T.J. Biesiadny, R.E. Grey and M. Abdelwahab

NASA, Lewis Research Ctr., Cleveland, OH., Rept. No. NASA-TM-X-3385; E-8592, 31 pp (Apr 1976) N76-21213

Key Words: Fans, Turbine components, Noise reduction

Test variables were inlet Reynolds number index (0.2 to 0.5), flight Mach number (0.2 to 0.8), and flow distortion (tip radial and combined circumferential - tip radial patterns). Results are limited to fan bypass and overall engine performance. There were no discernible effects of Reynolds number on fan performance. Increasing flight Mach number shifted the fan operating line such that pressure ratio decreased and airflow increased. Inlet flow distortion lowered stall margin.

76-2008

Added Mass of Marine Propellers in Axial Translation

J.E. Brooks

David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD., Rept. No. DTSNRDC-76-0079, 16 pp (Apr 1976) AD-A025 250/2GA

Key Words: Marine propellers, Disks, Resonant frequency

Experimental and theoretical values are compared for the added masses of marine propellers and disks in axial translation. The experimental apparatus and procedure are described in detail, but the theoretical model is only outlined. Values predicted by the theoretical model were 15 to 30 percent smaller than the experimental results, except for the case of a circular disk in broadside motion where the results agreed within 2 percent. The generation of vorticity on the surfaces of the propellers and disks is proposed as a possible explanation for the discrepancies.

RAIL

76-2009

Steering and Dynamic Stability of Railway Vehicles

A.H. Wickens

British Rail Res. and Dev. Division., Derby, England, Vehicle Syst. Dyn., 5 (1-2), pp 15-46 (Aug 1975) 11 figs, 21 refs

Key Words: Railroad vehicles, Dynamic stability, Steering effects

For railway vehicles having coned wheels mounted on solid axles there is a conflict between dynamic stability and steering ability. It is shown that the stiffness and kinematic properties of all possible interwheelset connections are characterized by two properties describing the distortional characteristics of the vehicle in plan. Within this framework, the various possibilities for steered wheelsets are considered, and several past and current proposals are reviewed. Using the linear approach to dynamic stability and curve negotiation the performance of existing and newly proposed configurations is discussed.

76-2010

The Dynamics of Single Track Vehicles

R.S. Sharp

Dept. of Mechanical Engrg., The Univ. of Leeds, Leeds LS2 9JT, England, Vehicle Syst. Dyn., 5 (1-2), pp 67-77 (Aug 1975) 16 refs

Key Words: Monorail railways, Steering effects

The paper contains a brief review of the more subjective aspects of the steering behavior of single track vehicles, a review of the more significant published work in the field, and an assessment of the current state of understanding and likely ways in which further progress can be made. Attention is drawn to the many areas of agreement between theory and practice and to some areas of disagreement. The greatest need now seems to be for the incorporation of more complex tire models into vehicle handling models.

REACTORS

76-2011

A Method for Systematic Interpretation of Dynamic Measurements in a High Temperature Gas-Cooled Reactor

S.-I. Chang

Ph.D. Thesis, The University of Tennessee, 1976,
234 pp
UM 76-17, 720

Key Words: Nuclear reactors, Mathematical models, Parameter identification techniques

This study presents the development and application of a new technique for practical parameter identification of systems whose dynamics are described by up to 110 first order, linear differential and algebraic equations. A partitioned matrix technique was developed for this purpose. This technique which takes advantage of the matrix form of the system equations, constitutes a very efficient analysis algorithm when implemented on the digital computer. The identification procedure is to be used to analyze test results from the Fort St. Vrain high temperature, gas cooled reactor.

RECIPROCATING MACHINE

(Also see No. 1919)

76-2012

Truck Noise III-H. Final Report on the Freightliner Quieted Truck Program

T.D. Hutton, Jr.

Bolt Beranek and Newman, Inc., Cambridge, MA.,
Rept. No. DOT/TST-76-55, 57 pp (Jan 6, 1976)
(prepared in cooperation with Freightliner Corp.,
Portland, OR., see also PB-246 263)
PB-251 680/5GA

Key Words: Motor trucks, Engine noise, Diesel engines, Noise reduction, Acoustic measurement

This report summarizes the results of Freightliner's research, evaluation, and demonstration of diesel truck noise control efforts for the Quiet Truck Program sponsored by the Department of Transportation's Office of Noise Abatement. A synopsis of each of the seven previous Freightliner/DOT 'Truck Noise 3' reports documenting the various aspects of the program is provided. Significant conclusions are presented from the findings of these reports, along with a number of factors that must be considered to establish a proper perspective for evaluating these findings.

ROAD

(Also see Nos. 1881, 1886, 1913)

76-2013

Stochastic Road Inputs and Vehicle Response

J.D. Robson and C.J. Dodds

Dept. of Mechanical Engineering, Univ. of Glasgow,
Scotland, Vehicle Syst. Dyn., 5 (1-2), pp 1-13 (Aug
1975) 37 refs

Key Words: Ground vehicles, Automobiles, Stochastic processes, Road roughness, Spectral analysis

The paper explains the basis of the standard spectral techniques which are available for the description and analysis of stochastic processes, and emphasizes the restrictions implied by their acceptance. Progress towards the present state of the art is indicated by reference to work published over the last 25 years; this work has established that a stationary gaussian stochastic process does provide a satisfactory basic model for a road surface, and it has now reached a state of considerable sophistication. The development of experimental simulation techniques, based on multivariate stochastic process theory, is described and the relationship of such tests to response analysis is explained. There is some discussion of the probable directions of future progress. The presentation is based primarily on the automobile response problem, but many of the techniques described are applicable also to other forms of vehicle.

76-2014

Analysis and Interpretation of Steady-State and Transient Vehicle Response Measurements

N.F. Barter

The Motor Industry Res. Association, Nuneaton,
England, Vehicle Syst. Dyn., 5 (1-2), pp 79-103
(Aug 1975) 8 figs, 63 refs

Key Words: Ground vehicles, Steering effects, Periodic response, Transient response

This paper is concerned with the description of the open loop response of road vehicles to steering inputs. The important literature is reviewed for both steady state and transient response behavior. The measures available for steady state response covering the whole range of lateral acceleration are discussed in detail, and sample measured data are presented. It is shown that the important quantities are the effective cornering stiffnesses of the front and rear tires, how they are related, and how they vary with lateral acceleration. Transient response is only considered for the region of linear behavior, where it is seen that a control theory approach is appropriate. A sample set of frequency response curves and step input responses are presented. It is concluded that satisfactory methods of measurement and description are available but that 'desirable' levels cannot yet be firmly specified.

76-2015

Simulation of Directional Behaviour of Road Vehicles

U. Sorgatz

Volkswagenwerk AG, Wolfsburg, Germany, Vehicle Syst. Dyn., 5 (1-2), pp 47-66 (Aug 1975) 12 figs, 35 refs

Key Words: Digital simulation, Ground vehicles

This paper contains a review of simulations of the dynamic behavior of vehicles to directional road planar/inputs.

76-2016

On the Stability in the Sense of Liapunov of a Rubber Tire Vehicle

H.K. Sachs and C.C. Chou

Wayne State Univ., Detroit, MI., J. Dyn. Syst., Meas. and Control, Trans. ASME, 98 (2), pp 180-185 (June 1976) 2 figs, 13 refs

Key Words: Ground vehicles, Stability, Tire characteristics

A qualitative evaluation of the vehicle stability problem is given for the purpose of establishing a measure of the performance limit of automobiles for the imposed conditions of constant speed and fixed steer control.

76-2017

Investigation of Fluidically Controlled Suspension Systems for Tracked Vehicles

W.R. Eberle and M.M. Steele

School of Aeronautics, Astronautics and Engineering Sciences, Purdue Univ., Lafayette, IN., Rept. No. TACOM-TR-12072, 96 pp (Sept 1975) AD-A022 636/5GA

Key Words: Tracked vehicles, Suspension systems (vehicles), Mathematical models

Thus use of fluidic components in a hydropneumatic suspension system is expected to significantly improve certain performance characteristics of the suspension system. Several candidate variable damping and variable springing systems are discussed. The damping and springing parameters are functions of relative position (between the wheel and the vehicle body), relative velocity, and vertical acceleration of the vehicle body. A mathematical model is derived for each candidate system. A brief performance analysis of selected systems is presented.

ROTORS

76-2018

Unsteady Drag and Dynamic Stall as Simulated in a Varying Freestream

D.L. Kunz

Ph.D. Thesis, Georgia Institute of Technology, 1976, 189 pp UM 76-16, 984

Key Words: Helicopter rotors, Rotary wings, Stalling

The objectives of this investigation were to find out to what extent streamwise, simple harmonic velocity perturbations in the freestream affect dynamic stall and unsteady drag.

76-2019

The Application of Gas- and Oil-Lubricated Foil Bearings for the ERDA/Chrysler Automotive Gas Turbine Engine

S. Gray, N. Sparks and J. McCormick

Mechanical Technology, Inc., Latham, NY., ASME Paper No. 76-GT-115

Key Words: Rotor-bearing systems

A design study has been made of a resilient hydrodynamic foil bearing support system for a 58,500-rpm automotive gas turbine rotor utilizing an air-lubricated journal bearing at the hot turbine end and an oil-lubricated journal and thrust bearing at the compressor end. The paper includes a review of earlier engine rotor/bearing systems and lists the potential advantages of the foil bearings. Design analysis of the bearings and rotordynamics is given including critical speeds, rotor unbalance response, bearing performance, and temperature distributions to confirm the feasibility.

76-2020

An Empirical Design Procedure for Shafts with Fatigue Loadings

J.D. Grounds

Darcom Intern Training Center, Texarkana, TX., Rept. No. DARCOM-ITC-02-08-76-017, 40 pp (Apr 1976) AD-A024 785/8GA

Key Words: Shafts, Fatigue strength, Design techniques

This report presents a method of designing rotating shafts subjected to combined fatigue loads. In the past, the fatigue strength, a material property necessary for design, has been determined for axial, bending, and torsional loads independently. A general approach to design with combined loads requires a fatigue strength that does not depend on the type of loading. Measured differences in the fatigue strengths are attributed to the size of a shaft. By developing correction factors to be used on the applied bending and torsional loads, the axial fatigue strength can be used for combined loads.

SATELLITE

(See No. 1931)

SPACECRAFT

(Also see Nos. 1895, 1896, 1897, 1967, 1997)

76-2021

Effects of Unsymmetrical Stability Derivative Characteristics on Reentry Vehicle Transient Angular Motion

A.E. Hodapp, Jr.

Sandia Labs., Albuquerque, NM., Rept. No. SAND-75-0252, 37 pp (Sept 1975)

N76-23174

Key Words: Reentry vehicles, Stability analysis

Analytical results, numerical results, and results of digital flight simulations are presented for an investigation of the effects that unsymmetrical stability derivative characteristics have on the transient angular motion of slender rolling reentry vehicles. It is shown that in addition to changing the motion patterns, damping, and frequency relative to those for symmetrical missiles, unsymmetrical stability derivatives can cause an exponential growth of the transient angle of attack for flight conditions within the resonance region.

76-2022

Analysis of Structural Dynamic Data from Skylab. Volume 1: Technical Discussion

L. Demchak and H. Harcrow

Martin Marietta Corp., Denver, CO., Rept. No. NASA-CR-144285; MCR-76-179-Vol-1, 222 pp (Mar 1976)

N76-22269

Key Words: Spacecraft

A compendium of Skylab structural dynamics analytical and test programs is presented. These programs are assessed to identify lessons learned from the structural dynamic prediction effort and to provide guidelines for future analysts and program managers of complex spacecraft systems. It is a synopsis of the structural dynamic effort performed under the Skylab Integration contract and specifically covers the development, utilization, and correlation of Skylab Dynamic Orbital Models.

76-2023

Analysis of Structural Dynamic Data from Skylab. Volume 2: Skylab Analytical and Test Model Data

L. Demchak and H. Harcrow

Martin Marietta Corp., Denver, CO., Rept. No. NASA-CR-144286; MCR-76-179-Vol-2, 216 pp (Mar 1976)

N76-22270

Key Words: Spacecraft, Mode shapes

The orbital configuration test model data, analytical test correlation model data, and analytical flight configuration model data are presented. Tables showing the generalized mass contributions (GMCs) for each of the thirty tests modes are given along with the two dimensional mode shape plots and tables of GMCs for the test correlated analytical modes. The two dimensional mode shape plots for the analytical modes and uncoupled and coupled modes of the orbital flight configuration at three development phases of the model are included.

76-2024

Shuttle On-Pad Ground Wind Loads

A.D. Devers, E. Simon, T.E. Blejwas, and A.C. Park
Martin Marietta Corp., Denver, CO., Rept. No. NASA-CR-144290; MCR-75-446, 285 pp (Apr 1976)

N76-23623

Key Words: Spacecraft, Wind-induced excitation, Computer programs, Towers

A digital computer program system capability was developed which includes: (1) the ability to generate both static and dynamic load components and resultants for all wind azimuths due to drag, gusts and/or wind induced oscillations; (2) the ability to establish both static and dynamic components and resultant deflections versus vehicle station for the separate shuttle system components; (3) the ability to analyze the dynamic loads and responses resulting from Orbiter ignition/shutdown (rebound phenomena); and (4) the ability to combine structural loads and deflections from different load sources.

76-2025

Coupled Base Motion Response Analysis of Payload Structural Systems

A.D. Devers, H. Harcrow and A.R. Kukreti
College of Engrg. and Applied Science, Colorado Univ., Boulder, CO., Rept. No. NASA-CR-144291; UCCE-75-2, 113 pp (Apr 1976)
N76-23624

Key Words: Coupled response, Component mode analysis, Spacecraft

Coupled base motion response analysis of payload structural systems is discussed. A systems analysis program is described which by component analysis structural transient response analyses can be completed. The program presents a proven technique, used initially on the Skylab program, which is designed to reduce cost and schedule time on detail structural analyses of structural payload systems. Base motion procedures are employed where critical segments of complex structural systems or components may be analyzed for various load conditions without having to re-establish the entire structural system coupled model properties. The transient response characteristics of a complex structural system are used as a basis for evaluating the transient response of a similar system.

76-2026

Analytical Prediction of Motor Component Vibrations Driven by Acoustic Combustion Instability

F.R. Jensen
Hercules Inc., Systems Group, Wilmington, DE., Rept. No. AFRPL-TR-76-11, 656 pp (Feb 1976)
AD-A025 261/9GA

Key Words: Solid propellant rocket engines, Combustion noise, Oscillation, Finite element technique, Computer programs

A detailed investigation has been conducted on the structural dynamic response of solid rocket motors. The study was particularly concerned with estimating the structural response to unstable acoustic combustion oscillations that often occur in solid motors during motor firing time. Detailed finite element analyses were performed on the Poseidon C-3 second stage motor and on the Minuteman III third stage motor using a NASTRAN computer program. In addition, the response of an inert second stage Poseidon C-3 motor to internal acoustic excitation was measured during an experimental task.

76-2027

Suspension for Missile Equipment: Measurement of the Dynamic Characteristics of Viscoelastic Materials Utilizable as Dampers

J. Moriceau
Laboratoire de Recherches Balistiques et Aerodynamiques, Vernon, France, Service Environnement et Metrologie, Rept. No. LRBA-E-1-300-1/SEM, 90 pp (June 1975)
(In French)
N76-22552

Key Words: Spacecraft equipment, Equipment mounts, Viscoelastic damping

Tests were carried out to determine the dynamic stiffness and damping of some viscoelastic materials, in order to develop a catalog of viscoelastic materials to be used in shock or vibration damping systems including not only their chemical and mechanical properties but also their dynamic characteristics as function of some parameters. The principles of the method for the measurement of dynamic characteristics are presented and results discussed. The influence of temperature and specimen geometry is evidenced. The use of polyurethane elastomers in damping systems, over rubber and polyester foams, is emphasized.

STRUCTURAL

(Also see No. 1898)

76-2028

Overturning and Sliding Analysis of Reinforced Concrete Protective Structures

W. Stea, S. Weissman, N. Dobbs and P. Price
Ammann and Whitney, NY., Rept. No. PA-TR-4921, 279 pp (Feb 1976)
AD-A022 619/1GA

Key Words: Protective shelters, Reinforced concrete, Blast resistant structures, Interaction: soil-structure, Computer programs

This report presents design procedures and the computer program written to implement them for determining the gross motions of protective structures subjected to blast effects of high explosive detonations. These procedures are intended to supplement the design methods of the tri-service design manual 'Structures to Resist the Effects of Accidental Explosions' (TM 5-1300). The material presented includes dynamic analysis techniques for determining the gross motions of the structure on its supporting soil, methods for computing the time history of the blast load on the structure, and criteria and procedures for designing the foundation of the structure. A system of classification of various soils is given together with a tabulation of critical soil properties.

TURBOMACHINERY

(Also see Nos. 1935, 1937)

76-2029

Experiments on Oil-Film Dampers for Turbomachinery

M. Botman

Pratt & Whitney Aircraft of Canada, Ltd., Longueuil, Quebec, Canada, J. Engr. Power, Trans. ASME, 98 (3), pp 393-400 (July 1976) 15 figs, 8 refs
ASME Paper No. 75-WA/GT-19

Key Words: Fluid-film damping, Turbomachinery

Oil-film dampers are used in turbomachinery to suppress undesirable shaft dynamic responses. They are located at the nonrotating outer race of selected main bearings. A rig is described that was designed to evaluate the effect of damper geometry on the rotor responses. Typical test results are shown which indicate that cavitation limits the maximum speed at which dampers should be used.

76-2030

Methods of Dynamic Measurements in Turbomachines

R. Larguier and A. DeSieviers

Royal Aircraft Establishment, Farnborough, England, Rept. No. RAE-Lib-Trans-1835; BR51462; ONERA-TP-1403-(1974), 26 pp (Jan 1976) (Transl. into English from L'Aeronautique et L'Astronautique (France), 46, pp 9-18 (1974); ONERA-TP-1403-(1974)
N76-22542

Key Words: Turbomachinery, Measurement techniques

The work at ONERA on dynamic measurements in turbomachines, which extends from incompressible to supersonic flow is reported. Data on surface pressures on moving blades and on the external casing, opposite the rotor, and on determination of the wake by pressure sensor and hot wire are presented.

76-2031

Determination of the Time-Averaged Pressures in Strongly Fluctuating Flows and Especially in Turbo-Machines

H. Weyer

Royal Aircraft Establishment, Farnborough, England, Rept. No. RAE-Lib-Trans-1850; DLR-FB-74-34, 145 pp (Jan 1976) (Transl. into English from Deutsche Luft- und Raumfahrt, Rept. No. DLR-FB-74-34)
N76-22543

Key Words: Turbomachinery, Dynamic response, Measuring instruments

The problems of measuring pressure are studied for strongly fluctuating flow - for example, in turbomachines - with particular regard to the determination of clearly defined average pressures. A detailed description is given of the operating principles of three new procedures for determining the actual time averages of pressure fluctuations of high frequency and amplitude and also of the construction of the corresponding measuring devices. Laboratory testing of these procedures is reported using a newly developed calibration device that generates defined pressure fluctuations, and initial tests of the measuring devices in turbocompressors are described.

ANNUAL AUTHOR INDEX

Abdel Sayed, R.K.	214	Allen, J.M.	540	Atencio, Jr., A.	402
Abdelwahah, M.	2007	Amartin, R.	811	Atluri, S.	117
Abel, I.	283, 1048	Amba-Rao, C.L.	109	Auer, F.	1511
Aboudi, J.	49	Amiet, R.K.	188, 1352	Auerbach, J.M.	778, 1599
Abou-Sayed, A.S.	1019	Amir, G.	1522	Austin, J.A.	601
Abuaf, N.	1359	Ammesdorfer, F.	318	Au-Yang, M.K.	737
Abu-Akeel, A.K.	1624	Ancher, L.J.	1895, 1896, 1897	Awojobi, A.O.	1771
Acosta, A.J.	1664, 1854	Anderbery, R.	367	Aylor, D.E.	1034
Adachi, J.	273	Anderes, J.R.	216, 459	Baade, P.K.	243
Adams, G.G.	819	Anders, H.	885	Babcock, C.D.	276
Adams, G.H.	177, 1519, 1520, 1881	Anderson, G.L.	376, 627, 629, 658, 664, 665, 1118, 1209, 1332, 1572	Bach, W.	1487
Adams, R.D.	236, 1750	Anderson, J.C.	41, 1839	Bachmann, W.	1546, 1547
Adelman, N.T.	82	Ando, Y.	1439	Backaitis, S.H.	991
Adkins, R.L.	661	Andrews, I.M.	1404	Backus, J.	190
Adler, A.A.	862	Andrews, J.J.	1259	Bacon, D.J.	234
Advani, S.H.	889	Angelopoulos, T.	1505	Badgley, R.H.	254, 297
Agarwal, R.R.	120	Angiola, A.J.	1150	Baer, W.H.	821
Ag'izim, A.M.	532	Ansari, J.S.	1901	Bagci, C.	93
Agliany, J.	1718	Anselm, D.	322	Bahar, L.Y.	211
Aguiar, A.A.	981	Aoyagi, K.	281, 568	Bai, M.	304
Aiken, T.N.	281, 568	Aoyama, T.	255	Bailey, C.C.	553
Aitken-Cade, P.B.	1617	Apostolakis, G.E.	972	Bailey, C.D.	1119
Akay, A.	200	Appleby, M.R.	1083	Bailey, D.B.	716
Akay, H.U.	1823	Aramraks, T.	291	Bailey, D.C.	1147, 1148
Akesson, B.A.	222	Archibald, F.S.	32	Bailey, J.R.	200, 302, 306
Akin, J.T.	295	Archuleta, R.J.	64	Baird, B.C.	1227
Akiyama, K.	827	Ardayfio, D.	1713	Baird, E.F.	425
Akkas, N.	1825	Argyris, J.H.	1505, 1508, 1509, 1510	Baird, G.T.	367
Aksu, G.	1231	Ariga, I.	1678	Baker, D.D.	235
Alakel, M.N.	729	Armen, H.	1876	Baker, W.E.	1626, 1894
Alberti, F.P.	1210	Armstrong, E.L.	984	Balcerak, J.C.	1099
Alda, W.	812	Arnold, G.A.	1088	Baldock, J.C.A.	418, 633
Alexander, E.M.	1777	Arnoldi, R.A.	256	Ballato, A.	533, 1873
Alexandre, A.	1256	Arora, J.S.	258, 1625, 1785	Balsa, T.F.	1477
Alfaro-Bou, E.	1914	Arya, A.S.	842, 843	Balsara, J.P.	1842
Alfredson, R.J.	873	Arya, S.C.	1274	Ban, Y.	462
Algermissen, S.T.	208	Asada, H.	1832	Banerjee, B.B.	374
Al-Hassani, S.T.S.	87	Asfura, A.	1063	Banerjee, S.	1802
Ali, M.R.	158	Ashworth, R.P.	1252	Bang, A.J.	1737
Ali, R.	1231	Atalik, T.S.	1725	Bannister, R.L.	484
Ali, S.A.	211	Atanasiu, N.	1284	Bannister, R.W.	876
Allaire, P.E.	612, 1702, 1703			Bansal, P.N.	79
Allan, D.W.	242			Barach, D.	189, 1875
Allen, G.R.	445, 1337			Barber, J.P.	1637

Barbero, P.	642	Bennett, B.E.	1549	Bobbert, G.	446
Barbin, A.R.	330	Bennett, R.L.	519	Bobby, W.	1458
Barcilon, V.	1575	Benson, J.B.	600	Bockemohle, P.	1396
Barclay, D.W.	855, 977	Bentley, P.G.	1855	Bodle, J.G.	720
Barducci, I.	711	Benveniste, Y.	6, 1827	Bodlund, K.	1390, 1405
Barile, A.J.	535	Benzley, S.E.	1436	Boers, B.L.	101
Barker, S.J.	1380	Beredugo, Y.O.	1765	Boghani, A.B.	527
Barnes, G.R.	447	Berens, A.P.	441	Bogy, D.B.	819
Barniskis, A.E.	1513	Beres, D.P.	553	Bohn, G.J.	630
Baron, F.	1646, 1647	Berger, B.S.	555	Boisseau, J.F.	809
Barr, A.D.S.	154, 155, 1252	Bergmann, E.P.	768	Bojadziev, G.N.	1322
Barrett, L.E.	612	Berkau, E.E.	771	Bolen, J.L.	1242
Barrett, S.	1719	Berkofske, K.	1668	Bolger, J.C.	973
Barschdorff, D.	379	Bernard, J.	1084	Bolgov, V.M.	939
Bartel, C.	194	Bernussou, J.	764	Bolleter, U.	1579
Bartel, D.L.	20	Berry, V.L.	492, 493	Bolt, B.A.	42
Bartel, H.W.	1474	Bert, C.W.	849	Bondarenko, V.P.	779
Barter, N.F.	2014	Bertero, V.V.	900, 903, 1828	Bonnot, P.	793
Barth, E.W.	1705	Bertrand, J.C.	352	Book, W.J.	451
Barton, F.W.	1049	Bessey, R.L.	829	Boothroyd, G.	56
Barton, J.C.	1278	Bhat, S.T.	130	Bordone-Sacerdote, C.	653
Baskin, J.M.	440	Bhatia, K.G.	180, 640, 1148	Boresi, A.P.	165
Bassily, S.F.	859	Bichat, B.	1505	Borodachev, N.M.	551
Bathe, K.	1788	Bickerstaffe, R.	463	Borthwick, J.O.	340
Bathelt, H.	1869	Bien, K.	1853	Bose, A.	1125
Battis, J.W.	1172	Bies, D.A.	1774	Bosenberg, D.	1869
Battles, R.A.	382	Biesiadny, T.J.	2007	Bosma, R.	1587
Bauer, E.	1295	Billingsley, J.P.	1911	Bosman, C.	481, 483, 485
Baumgartner, S.L.	1515	Bills, G.R.	1147, 1148	Botkin, M.E.	1222
Baumstark, R.R.	1533	Bilwakesh, K.R.	201, 202, 203	Botman, M.	307, 2029
Bausch, W.	344	Bintz, L.J.	1083	Bouc, R.	375
Baylac, G.	31, 1597	Bird, T.A.	1605	Bouwkamp, J.G.	578, 579, 580, 899
Beaulieu, W.D.	224	Bishop, D.E.	405, 881	Bowcock, J.E.	28
Bechert, D.	1642	Bishop, R.E.D.	949, 1314	Bowers, D.G.	872
Beck, R.R.	1845	Biswas, R.N.	120, 1595	Bowers, G.	112
Beckemeyer, R.J.	380, 1942, 1943	Bjor, O.	654	Box, S.	920
Becker, H.	2	Black, H.F.	1584	Boyce, L.	2003
Beckwith, I.E.	1912	Black, R.J.	1253	Boyden, R.P.	1106, 1107, 1497
Beglinger, V.	1579	Blackerby, W.T.	887	Boylan, L.	1155
Behm, W.E.	1304	Blackmon, R.	583	Brady, A.G.	1746
Behrens, J.A.	1778	Blake, M.P.	1061	Brashears, M.R.	1874
Beliveau, J.	1731	Blandford, R.	356	Braun, K.A.	1508
Bell, K.	680	Bleasdale, P.A.	234	Braun, S.	1391
Belytschko, T.	761, 922, 1694, 1695, 1728	Bleich, H.H.	1029	Braunbeck, O.A.	1994
Bendat, J.S.	1321	Blejwas, T.E.	2024	Breen, J.E.	1987
Bender, E.K.	928, 1683	Blevins, R.D.	106, 226	Breeuwer, R.	1069
Ben-Menahem, A.	53	Block, P.J.W.	968	Brenden, B.B.	245, 247
Bennekens, B.	427	Blomquist, D.S.	803, 1000, 1527	Brennen, C.	1664, 1854
Bennett, B.	787	Blythe, A.A.	412	Brock, J.E.	909, 1849
		Boardman, R.A.	1908		

Broderson, A.B.	1844	Butt, L.T.	1556	Chang, C.H.	1409
Bronstad, M.E.	1304	Buxbaum, O.	1543, 1544	Chang, F.K.	524
Brooking, R.L.	797	Bycroft, G.N.	1491	Chang, N.	1462
Brooks, J.E.	2008	Bynum, J.D.	1663	Chang, P.H.	1798
Brooks, T.F.	302	Byrne, P.M.	1905	Chang, S.-I.	2011
Brown, D.	301	Cadoff, M.A.	466	Chang, Y.M.	846
Brown, D.G.	412, 1057	Cahill, J.F.	887	Chao, K.L.	554
Brown, J.	378	Calistrat, M.M.	1226	Chapman, P.	511
Brown, R.V.	1286, 1287, 2001, 2002	Cambou, J.P.	685, 1614, 1824	Chatelin, F.	1141
Brown, W.K.	490	Campbell, J.W.	617	Chattopadhyay, S.	111, 816
Browne, A.L.	1900	Cann, R.G.	1346	Cheeseman, I.C.	406
Browning, D.G.	876	Cannelli, G.B.	711	Chen, A.T.F.	46
Brownlee, G.R.	1500	Cannon, C.M.	220, 1488	Chen, F.Y.	95, 96
Bruce, R.W.	1694, 1695	Capps, A.	772	Chen, J.C.	276, 516, 1377
Brueggemann, W.H.	548	Captain, K.M.	527	Chen, K.H.	1124
Brumaghim, S.H.	449, 1177	Carden, H.D.	581	Chen, L.T.	419
Brune, G.W.	1130	Carlomagno, G.	1013	Chen, M.	431
Brune, J.N.	64	Carlson, A.	1696	Chen, P.Y.	835
Brunelle, E.J.	1233	Carnegie, W.D.	1077, 1690	Chen, S.S.	86, 113, 631, 836, 1596, 1927, 1939
Brunken, J.E.	492, 493	Carpenter, G.D.	1346	Chen, S.S.H.	277, 1620
Bryan, M.E.	1485	Carr, L.W.	976	Chen, T.C.	1149, 1150
Bryce, W.D.	1856	Carr, R.W.	290	Chen, T.L.C.	849
Brzozowski, V.J.	1423	Carson, W.W.	1797	Chen, W.L.	105
Buck, O.	1920	Carstens, V.	1020, 1021	Chen, Y.N.	868
Buckens, F.	1675	Carter, N.L.	1652	Cheng, D.Y.	694, 1666
Bucker, H.P.	959	Caruso, H.	1156	Cheng, F.Y.	1116, 1222
Buckingham, R.	938	Cary, B.B.	47	Cheng, Y.	1634
Buehlmeier, J.	1509	Casarella, M.J.	1583	Chernomorskiy, A.I.	473
Bufkin, M.P.	1987	Cassarino, S.J.	1276	Chernyl, G.I.	779
Bulteau, V.G.	1652	Cassot, F.	645	Cherry, J.T.	780, 1751
Bullen, R.	1345	Catherines, J.J.	408, 701, 1977	Cheshankov, B.I.	5, 754
Burcham, F.W.	1255	Cato, D.H.	1859	Chesta, L.	422
Burgess, D.N.	1187	Cattaneo, L.E.	1989	Chestnutt, D.	1677
Burgess, I.W.	1506, 1554	Caughey, T.K.	1127	Cheung, Y.K.	110
Burghardt, H.	1392	Ceci, B.L.	989	Childs, D.W.	1701
Burkes, J.M.	929, 930	Cermak, G.W.	1738	Chillery, J.A.	775
Burley, R.R.	1640	Cerneau, S.	1906	Chin, J.	642
Burney, F.A.	1658, 1999	Chadwick, R.S.	293	Chipman, R.R.	1108
Burns, R.J.	1981, 1983	Chaikin, G.	168	Chiu, J.S.	1648
Burns, S.L.	567	Chakrabarti, P.	979, 1386	Chivens, D.R.	153
Burnside, O.H.	1611	Chakrabarti, S.K.	83	Chohan, S.M.	1918
Burrow, Jr., L.R.	507	Chalupnik, J.D.	1698, 1699	Choi, C.K.	1721
Burt, G.E.	241, 1573	Chamis, C.C.	541, 1936	Chon, C.T.	1812, 1952
Burton, C.E.	1692	Chan, C.F.	1202	Chonan, S.	75, 1006
Burton, T.E.	226	Chan, S.T.K.	1874	Chopra, A.K.	979, 1386
Buschbeck, F.	1392	Chanaud, R.C.	1011	Chou, C.C.	2016
Bushnell, D.	1820	Chander, S.	1441	Chou, D.C.	50
Buth, C.E.	870	Chandra, J.	1548	Chou, P.C.	841
Butler, F.E.	338, 339, 515, 518	Chandran, K.B.	136, 856	Christensen, E.	1586
		Chandrasekharan, K.	127, 1442		

Christian, D.	1716	Coy, R.G.	441	Davis, A.M.J.	1759
Christie, D.R.A.	1630	Cozzarelli, F.A.	1144	Davis, R.E.	1267
Chu, S.-C.	94	Craggs, A.	1809	Davis, S.S.	840
Chu, S.L.	1117, 1841	Craig, D.M.	343, 1883	Dawkins, M.S.	1533
Chung, H.	393	Crandall, S.H.	137	Dawson, B.	22
Cicci, F.	1260	Crawford, F.R.	1152	Day, F.D.	1395, 1500
Clancy, T.M.	799	Crawford, J.	117	Day, H.	1275
Clapper, W.S.	202	Crego, H.L.	643	De, S.	1024
Clark, L.T.	1698, 1699	Crighton, D.G.	624	Deadrick, F.J.	1459
Clark, W.B.	425	Crimi, P.	584	Dean, L.W.	1961
Clarke, M.J.	1369	Crittenden, J.B.	1970	DeCapua, N.J.	1558
Clayden, A.D.	632	Crocker, M.J.	34, 721	De Choudhury, P.	1705
Clements, D.L.	1008	Cromack, J.R.	929, 930	Deckker, B.E.L.	1220
Clevenson, S.A.	443, 1370	Cronin, D.L.	68	deClercq, H.	1990
Cliff, E.M.	716	Cronkrite, J.D.	492, 493	Defebvre, A.	1191
Clifton, R.J.	1019	Crossley, F.R.E.	97, 98	DeHart, R.C.	1993
Clise, R.A.	66	Crouse, C.B.	44, 1743	Deicke, H.	25
Close, W.H.	927, 1886	Crowder, J.P.	1039	DeJonge, J.B.	1975
Clough, R.W.	215, 706, 1249, 1744	Cryer, B.W.	1092	Delaney, R.A.	1937
Coakley, W.T.	1185	Culley, R.W.D.	632	DeLapp, R.E.	1258
Coates, G.D.	1371	Cummings, D.	574	Demchak, L.	2022, 2023
Cobble, M.H.	1417	Cumpsty, N.A.	596	DeMey, G.	333
Coe, H.H.	1932	Cunningham, R.E.	77, 151	Dempsey, T.K.	1371, 1373
Cohen, H.	1953	Curran, J.W.	1769	Denham, R.N.	876
Cole, J.E.	1807	Curtis, A.J.	37	Dennis, A.J.	608
Coleby, J.R.	1448	Curtis, A.R.	1526	Dennison, E.E.	1073
Coleman, D.J.	1265	Czogala, E.	1613	Denver, R.E.	1334
Collacott, R.A.	1200	Daggerhart, J.A.	306	Derentowicz, H.	534
Conaway, J.H.	615	Dally, J.W.	219	Deresiewicz, H.	121
Conle, A.	362	Dammig, V.P.	25	Der Kiureghian, A.	1749
Conrad, E.W.	693, 1291	Danay, A.	1837	Desai, A.R.	1946
Conway, J.J.	1161	Dancer, A.	1645	Desayi, P.	1740
Cook, R.K.	998	Dandage, S.	745	Deshpande, R.B.	483
Cooper, W.A.	721	Danforth, C.E.	257	DeSiewers, A.	2030
Cooperrider, N.K.	145	Dange, Y.K.	1310	deSilva, B.M.E.	831, 832, 1425, 1800
Cops, A.	26	Daniele, C.J.	502	DeSilva, C.W.	1279, 1789
Cordie, S.R.	771	Daniels, V.A.	1095	DesPlanques, P.	1191
Corley, D.M.	1000, 1527	Dao, N.V.	488, 489	Destuynder, R.M.	240, 417, 561
Cornillon, P.C.	1738	Daoud, A.T.	1120	DeTricaud, P.	894
Cornwell, P.E.	1238	Darlow, M.S.	254	Devenny, D.W.	907
Corotis, R.B.	206, 433	Das, M.D.	7	Devers, A.D.	2024, 2025
Costello, G.A.	869	Das, R.N.	374	Dharmarajan, S.	1270
Cottney, D.J.	278	Dasgupta, G.	979, 1386	Diachok, O.I.	1350
Coull, A.	133	Dash, P.K.	1354	Dickerson, J.R.	337
Coulson, J.	1687	da Silva Nunes, L.F.P.	1218	Dickey, J.W.	225, 1806
Coulter, G.A.	582, 895	Daube, W.M.	1805	Dickinson, S.M.	859
Covill, E.F.	1650	D'Auria, P.V.	1147, 1148	Diedrich, J.H.	987
Cox, J.J.	1293	Davenport, E.E.	1106, 1497	Diehl, G.M.	1290
Cox, P.A.	1894	Davies, M.	22	Dieterich, D.A.	230
Coy, J.J.	383, 1600	Daviet, J.T.	619		

Dietrich, G.	1508	Duperray, B.	1537	Everstine, G.C.	494
Dimarogonas, A.D.	163	Duran, R.	107	Ewins, D.J.	278, 1420, 1935
DiMasi, F.P.	738	Durham, D.J.	1145	Ezzat, H.A.	1588
Dimentberg, Jr., M.F.	752	Durlofsky, H.	818	Faccioli, E.	1763
Dimoff, K.	239	Durvasula, S.	1954	Fahy, F.J.	1414, 1495, 1949
DiNapoli, F.R.	766	Dustin, M.O.	676	Falarski, M.D.	281, 568
Director, M.N.	785	Dusto, A.R.	1130	Fan, C.	521
Distefano, N.	621	Dym, C.L.	1028, 1384, 1726	Fancher, P.	1084
Dittmar, J.H.	830, 2005	Dyman, R.A.	1376	Fantino, R.E.	559
Dittrich, G.	1327, 1850	Dyson, A.	1015	Farassat, F.	937
Dixon, S.C.	1049	Dzygadło, Z.	552, 883, 1821	Farmer, M.G.	1972
Dizioğlu, B.	1957	Eade, P.W.	463	Farshad, M.	1928
Dmitriev, A.I.	916	Earles, S.W.E.	1697	Fashbaugh, R.H.	216
Dobbs, N.	2028	Eberle, W.R.	1631, 2017	Fatz, J.C.	985
Dobrzynski, W.	1562	Edmondson, A.J.	1656	Faulkner, L.L.	548
Dodds, C.J.	38, 2013	Edwards, D.H.	381	Fedberg, J.J.	35
Dodge, F.T.	829	Edwards, G.F.	702, 703	Fedotov, A.I.	915
Doepker, P.E.	835	Edwards, R.G.	1844	Feiler, C.E.	407, 1291
Doggett, Jr., R.V.	1387	Egbert, T.	931, 932	Felker, R.L.	1561
Dokainish, M.A.	310	Egorov, N.F.	1100	Felszeghy, S.F.	978
D'Oliverira, J.M.	159	Eldred, K.M.	349	Felton, L.P.	1612
Dominguez, R.F.	436	Eliezer, C.J.	1121	Feng, G.C.	1378
Donaldson, B.K.	1441	Elishakoff, I.	394, 1143, 1452	Feng, T.T.	258, 1785
Doolan, P.	139	Elliott, T.W.	1198	Ferris, M.	1652
Dorian, R.A.	510	Elmaraghy, H.A.	1545	Ferritto, J.M.	1752
Dornfeld, G.M.	1130, 1148	Elmaraghy, W.H.	310	Fertis, D.G.	1153
Dougherty, M.R.	1482	Elrod, W.C.	1563	Fieldhouse, I.B.	768
Dovey, H.H.	707	Ely, R.A.	728	Findley, D.S.	432, 569
Dowell, E.H.	331, 850	Elyasberg, M.E.	919	Fink, M.R.	623, 776, 1352
Doyotte, C.	1671	Embleton, T.F.W.	1035, 1036	Finke, H.O.	409
Dragan, O.	1192	Emery, A.F.	1797	Finn, W.D.L.	1905
Drake, J.L.	526	Emmerling, J.J.	202, 203, 593	Firth, D.	1855
Drake, M.L.	1402	Endo, N.	824	Fischer, E.G.	1805
Drane, D.A.	1041	Engel, P.A.	99	Fischer, G.	736, 1294
Dravinski, M.	1903, 1904	Engin, A.E.	1955	Fischer, V.D.	857
Drees, H.M.	369	English, J.W.	1103	Fisher, R.L.	1527
Drewyer, R.P.	1274	Enserink, E.	933	Fitzgeorge, D.	21, 1711
Dreyer, W.	1270	Epstein, H.I.	971	Fitzpatrick, M.	931, 932
Driels, M.R.	682	Erickson, L.B.	540	Fleck, J.T.	338, 339, 515, 518
Drosjack, M.J.	439	Erickson, P.A.	337, 1722	Fleming, D.	151
D'Souza, A.F.	1661	Eriksson, R.H.	608	Fleming, D.B.	135
Dubigeon, S.	149	Ertepinar, A.	114, 1823	Fleming, D.P.	297
Duffey, T.A.	1607	Ervin, R.	1084	Flottorp, G.	1059
Dugundji, J.	1208	Eshleman, R.L.	1131	Flynn, D.R.	803
Duke, J.C.	514	Esparza, E.D.	1894	Flynn, O.E.	1343
Dukes, R.E.	1288	Espinosa, A.F.	208	Foerschling, H.	606
Dunens, E.K.	1775	Evani, S.R.M.	279	Fontanet, P.	471
Dunlap, W.A.	436	Evensen, D.A.	1333	Ford, A.G.	263
Dunn, J.R.	330	Evernden, J.F.	781, 782	Forrer, J.S.	1000, 1527
Dunne, P.C.	1505	Eversman, W.	542	Forrestal, M.J.	1923

Forshaw, S.E.	452	Gates, J.H.	1267	Goldhammer, M.I.	1039
Fortenberry, J.W.	1499	Gates, R.M.	361, 498	Goldman, H.I.	975
Foster, J.E.	67, 304	Gaub, F.	323	Goldman, R.G.	1665
Foutch, D.A.	902	Gaukroger, D.R.	1041	Goldsmith, W.	978
Fowles, P.E.	1010	Gause, L.W.	820	Golubev, V.S.	370
Fowlie, D.W.	457	Gavriliv, M.I.	532	Gong, C.	1124
Fowweather, F.	1199	Gawronski, W.	1890	Goodall, R.G.	403
Fox, H.L.	727	Gee, S.W.	1362	Goodman, J.S.	697
Frandsen, J.D.	1920	Geisler, C.D.	1058	Goodno, B.J.	1064
Franke, M.E.	1581	Geislinger, L.	329	Goodykoontz, J.	570
Franke, R.	1645	Geissler, W.	1050	Gordon, G.	1155
Fredberg, J.J.	731	Gelder, T.F.	1074	Gordon, J.D.	805, 1565
Freeman, Jr., D.C.	1106, 1107, 1497	Geller, M.	1837	Gorholt, W.	1863
Freeze, T.W.	727	Gelman, A.P.	213	Gorman, D.J.	227
Freudenstein, F.	11	Genin, J.	1926	Gottlieb, J.J.	522
Freytag, G.	1910	Genkin, M.D.	299, 384, 385, 386, 401, 546	Graham, B.B.	964
Fricke, F.	1345	Gens, M.B.	1540	Graham, E.W.	964
Fridman, V.M.	1503	George, J.A.	1650	Grant, D.A.	817
Friedman, G.E.	1777	Gere, J.M.	1064	Grant, G.N.C.	831, 1425
Friedrich, H.	491	Gerresheim, M.	321, 1492	Grant, J.E.	1242
Frisk, G.V.	225, 1806	Gersch, W.	1532	Gray, A.	1121
Fritz, M.	753	Gershman, R.	677	Gray, C.H.	1652
Froboese, M.	359	Gertel, M.	1205	Gray, D.L.	283, 1048
Frohrib, D.A.	1713	Geschwindner, L.F.	251	Gray, S.	2019
Frolov, K.V.	717	Ghazvinian, B.	863	Green, A.T.	1781
Fry, J.T.	229	Giacaglia, G.E.O.	474	Green, D.R.	1425
Fryba, L.	1576	Giannotti, J.G.	1720	Green, J.L.	536
Frydman, A.M.	810	Gibbons, R.T.	1190	Greenbank, L.R.	1830
Frye, J.W.	496	Gibbons, S.L.	476	Greenberg, J.M.	1504
Fuchs, H.V.	1909	Gibson, R.F.	1755	Greene, J.E.	1305
Fujii, S.	144	Gieseke, R.K.	517	Greenfield, L.P.	529
Fujimori, Y.	577	Gilbert, G.	1254	Greenspon, J.E.	269
Funnell, W.R.J.	1264	Gillespie, M.D.	1533	Greenwood, G.H.	702
Furuike, D.M.	1122	Gilman, A.A.	551	Greer, H.	1799
Gaddy, L.	388	Givens, R.L.	603	Gregoire, J.P.	30, 1597
Galaitis, A.G.	712, 1683	Gladwell, G.M.L.	15, 84, 687, 1929	Gregory, R.A.	240
Galan, N.	1192	Glascok, L.A.	434	Greif, R.	393
Gallaway, B.M.	315	Gleason, P.T.	1420	Greitzer, E.M.	1673, 1674
Galleithner, H.	1978	Glöckner, W.	925	Grey, R.E.	2007
Galloway, W.J.	881	Gluck, J.	1837	Grier, J.H.	1539
Gangwani, S.T.	442	Gnatovski, I.I.	520	Griffin, J.H.	1796
Gantshev, I.	1783	Goatham, J.I.	1593	Griffin, M.J.	135, 1341
Garba, J.A.	516, 1377, 1500, 1717	Godby, L.	194	Griffin, O.M.	825, 1551, 1938
Garg, V.K.	311	Goel, R.P.	1792, 1794	Grigolyuk, E.I.	852
Garinther, G.R.	168, 1038	Goff, J.W.	530	Griner, G.R.	1536
Garnet, H.	1876	Goff, R.F.D.P.	1815	Grinkevich, V.K.	384, 385, 546
Gartner, J.R.	130, 223	Golden, L.	1696	Grins, W.	319
Gasch, R.	1870	Golden, M.E.	750	Griswold, T.F.	908
Gassel, S.S.	1822			Grönig, H.	784
				Grooms, D.W.	173, 1879, 1880

Grould, D.G.	585	Hannon, R.J.	1950	Herrmann, L.	1019
Grounds, J.D.	2020	Hansen, C.H.	1774	Herrmann, G.	175, 663, 681, 787, 1427, 1549
Guay, J.M.	239	Hanser, H.	1242	Herrmann, R.B.	1747, 1748
Gubbels, M.H.	313	Hanson, D.B.	455	Herron, D.J.	942
Gubser, J.L.	1173, 1644	Hanson, P.W.	1972	Hersh, A.S.	1891
Gunter, E.J.	151, 612, 1585, 1702, 1703, 1707, 1710	Hanson, R.D.	1007	Hershey, R.L.	567
Gupta, A.K.	1117, 1244, 1502	Harari, A.	1615	Hessel, R.E.	1480
Gupta, N.K.	1966	Harbarger, W.B.	1075	Hesser, R.J.	677
Gupta, P.K.	325	Harcrow, H.	2022, 2023, 2025	Heymann, F.J.	484
Gurfinkel, G.	1839	Hardy, A.E.J.	463	Hibben, S.	1155
Gusakov, I.	1086	Harland, D.G.	469	Hibi, A.	103
Guski, R.	409	Harper, C.R.	267	Hibner, D.H.	327, 1708
Gutfinger, C.	1359	Harris, P.	1169	Hidalgo, P.	215
Guy, C.N.	1916	Harris, T.	1889	Hieken, M.H.	1228
Haase, M.	1510	Harris, V.G.	201	Hill, C.R.	1060
Haber, J.M.	1151	Harris, W.L.	369	Hill, J.L.	942
Habercom, Jr., G.E.	169, 170, 172, 639	Harrison, T.D.	938	Hill, K.J.	1533
Hackley, D.S.	720	Hart, F.D.	771	Hill, M.J.	481, 483
Hadass, Z.	970	Hartnett, M.J.	1424	Hill, R.G.	599
Haddow, J.B.	974	Harvey, W.D.	874, 1912	Hill, R.S.	1018
Hadjian, A.H.	212	Hashmi, S.J.	87	Hilton, D.A.	882
Haering, R.R.	966	Hassig, H.J.	1473	Hindson, W.S.	585
Haftka, R.T.	1049, 1969	Hastings, E.C.	698	Hink, G.R.	1147, 1148
Hagiwara, I.	1080	Hatano, H.	990	Hinton, E.	1727, 1811, 1951
Hahn, E.J.	1590	Haug, Jr., E.J.	258, 1625	Hintz, R.M.	347
Haibach, E.	1543	Hausch, J.R.	530	Hirji, F.K.I.	1262
Haidl, G.	426	Havens, M.L.	360	Hirsch, T.J.	870
Haines, D.W.	1462	Hawkins, J.M.	797	Hobaica, E.C.	1132
Haisler, W.E.	1460	Hawks, R.J.	1423	Hodapp, Jr., A.E.	2021
Halda, E.J.	1751	Hay, B.	636, 893	Hodge, D.C.	168, 1038
Hale, M.E.	1602	Hayashi, S.	17, 18	Hodges, D.H.	663
Hall, J.W.	536	Hayden, R.E.	1669	Hodges, G.E.	282
Hall, R.	248	Hayes, G.G.	1301	Hodges, R.N.	529
Hall, R.M.	1360	Hays, W.W.	52, 208	Hodgson, D.C.	28
Hall, Jr., W.E.	1966	Healey, A.J.	1366	Hodgson, T.H.	200
Halle, H.	101	Hedrick, J.K.	459	Hoenlinger, H.	563, 1917
Hallquist, J.O.	1375	Hefner, R.E.	1278	Hofman, J.	1009
Hamati, R.E.	1646, 1647	Heidelberg, L.J.	407, 454, 1665	Hogg, G.W.	439
Hamilton, E.L.	960	Heidmann, M.F.	456, 2006	Hognestad, H.	654
Hamilton, K.G.	1751	Heller, H.	968	Hold, A.	146
Hamm, D.P.	961	Helms, H.	1733	Holland, C.J.	758
Hammel, J.	1826	Hemmig, F.G.	1619	Hollin, K.A.	1199
Hammond, C.E.	1387	Hempstock, T.I.	719, 1653	Hollings, J.P.	707, 899
Hampton, W.H.E.	1535	Henderson, D.M.	1147, 1148	Holloway, D.C.	246
Han, K.W.	1126	Henderson, F.M.	750	Holmer, C.I.	1003, 1292, 1571
Hancock, R.N.	1137	Henderson, H.R.	569	Holmes, D.G.	1168
Hänel, D.	784	Henderson, J.P.	1402	Holmes, N.	1728
Hanks, T.C.	1745	Hensing, P.C.	1472	Holmes, P.J.	1326
		Herbich, J.B.	1898	Holst, T.L.	786
		Herbst, H.C.	399		

Holt, M.	1360	Ibrahim, R.A.	155, 154, 1464	Jensen, F.R.	2026
Holy, Z.J.	73	Ice, M.W.	498	Jensen, J.W.	1280
Holze, G.H.	165	Ichikawa, T.	103	Jha, S.K.	303, 1977
Holzer, S.	1243	Idriss, I.M.	1860	Jirsa, J.O.	1987
Homans, B.	197	Ilhamov, M.A.	1604	Joeger, M.A.	180
Homyak, L.	454, 1980	Imaichi, K.	308	Johns, D.J.	688, 689, 1183, 1215
Honaker, J.W.	1538	Imasu, K.	308	Johns, R.H.	1795
Honma, T.	275	Inasaki, I.	255	Johnson, G.E.	332
Hood, M.J.	1759	Ingram, J.K.	526	Johnson, G.R.	971
Hoogstraten, H.W.	3	Ingram, L.F.	526	Johnson, H.K.	1099
Hoover, R.M.	1893	Inman, R.V.	1920	Johnson, J.H.	315
Horner, H.E.	821	Inoue, N.	58	Johnson, M.R.	735, 741
Hornig, J.T.	1456	Irvine, H.M.	1796	Johnson, S.	640
Horvath, A.J.T.	755	Irwin, A.W.	1840	Johnson, W.	416, 607, 834, 860
Horvath, M.	1868	Isada, N.M.	1693	Johnson, Jr., W.G.	1040
Horvay, G.	98, 112	Ishida, Y.	148	Johnston, J.P.	547
Horwat, J.W.	864	Ishihara, T.	100	Johnston, R.A.	1276, 1313
Hosier, R.N.	882, 1056, 1099, 1528	Ishii, N.	308	Johnston, R.G.	42
Houser, D.R.	439	Ishikawa, H.	58	Johnstone, B.	598
Housner, G.W.	902	Israeli, M.	293	Jones, B.	1372
Howard, P.W.	796	Issid, N.T.	1810	Jones, D.I.G.	220, 221, 1401, 1488, 1803
Howe, M.S.	1193	Iwan, W.D.	59, 1122	Jones, I.S.	1736
Howell, L.J.	1079	Iwata, K.	1660	Jones, J.R.	487
Howells, R.W.	495	Iwatsuba, T.	1135	Jones, K.E.	228
Hovlett, J.T.	443, 1641	Iyengar, K.J.	683	Jones, M.H.	1199
Hrovat, D.	458	Iyengar, K.T.S.R.	1740	Jones, N.	657, 1574, 1922, 1924
Hsieh, J.S.	267	Iyengar, R.N.	1354	Jones, R.	1232, 1435
Hsu, C.S.	760	Jackson, C.	992, 993, 994, 995, 1309, 1335, 1398	Jones, R.D.	1068
Hsu, T.	1838	Jackson, G.M.	722	Jones, R.E.	709
Huang, C.C.	1237, 1451	Jacobs, W.R.	158	Jones, R.F.	756
Huang, H.	684	Jacobson, I.D.	1175, 1257, 1363	Jones, W.L.	454
Huang, T.	1134	Jacobson, M.J.	963	Jones, W.N.	1173
Hubbard, H.H.	414, 432, 693	Jacques, J.R.	1479	Joseph, M.G.	1483
Huckel, V.	432, 569	Jaeger, M.A.	640	Joshi, B.B.	1310
Huffington, Jr., N.J.	116, 1608	Jain, P.C.	670	Joyce, R.P.	807
Huggins, G.G.	712, 728	Jan, H.W.	212	Joyner, W.B.	45, 46
Hughes, P.C.	943, 1542	Jan, S.F.	1357	Juang, J.-N.	1111
Hughes, R.C.	966	Janeway, R.N.	1340	Junger, M.C.	878
Hullender, D.A.	460	Jansen, W.R.	1636	Jurukovski, D.	899
Hupton, J.R.	1494	JaQuay, P.T.	1394	Kabir, A.F.	182
Hurst, C.J.	1465	Jarzynski, J.	1428	Kachadourian, G.	1501
Huseyin, K.	1281, 1324	Jayachandran, P.	1065, 1271	Kaczkowski, Z.	667
Husmann, A.W.	321	Jeary, A.P.	1840	Kadman, Y.	1986
Huston, J.C.	1263	Jeffers, J.D.	280	Kage, K.	357
Huston, R.L.	705, 1480	Jeglum, P.M.	1239	Kagoroku, N.	308
Hutton, G.B.	1041	Jendrzeczyk, J.A.	1927	Kahn, L.F.	1007
Hutton, Jr., T.D.	2012	Jenkins, M.A.	350		
Hyland, D.C.	731	Jenkins, S.H.	453		
Hysing, T.	365	Jennings, P.C.	44, 902		

Kajio, Y.	1080	Kerstner, O.S.	1285	Koizumi, T.	1439
Kallis, Jr., S.A.	512	Kerwin, J.E.	941	Kojima, E.	100
Kamaya, S.	17, 18	Kester, J.D.	1852	Kojima, N.	1689
Kameda, H.	355	Kevala, R.J.	567	Kölzsch, P.	1853
Kamimura, H.	358	Key, S.W.	1436	Kong, N.	1011
Kana, D.D.	161, 620, 829, 1196, 1568	Khot, N.S.	336	Koopmann, G.H.	1351
Kanaka Raju, K.	1461	Khozeimeh, K.	1793	Kordes, E.E.	1526
Kanbe, Y.	1704	Kidun, S.M.	532	Korman, H.F.	1648
Kane, T.R.	1114	Kiefling, L.	1378	Kortesoja, V.A.	1081
Kanianthra, J.N.	57	Kikins, P.W.	312	Koster, M.P.	91
Kant, S.	1300	Kimball, C.E.	1993	Kosuge, H.	1678
Kao, A.	583	King, C.A.	617	Kounadis, A.N.	250, 252
Kaper, B.	3	King, C.N.	381	Kouts, C.A.	351
Kaplan, R.E.	1476	King, L.A.	353	Koval, L.R.	1833
Kar, A.K.	134	King, R.	1215	Koyanagi, R.S.	61
Karafiath, L.L.	1867	King, R.J.	344	Kozik, T.J.	2003
Karam, Jr., J.T.	1581	Kinns, R.	1343, 1478	Kraft, R.E.	1941
Karchmer, A.	1221	Kinsel, W.C.	1684	Krajcinovic, D.	74, 1550
Karchmer, A.M.	407	Kirby, C.A.	1997	Krenk, S.	1968
Karpek, M.	160	Kirby, R.H.	464, 1371	Kreyszig, E.	1325
Karvelis, A.V.	1947	Kirk, R.G.	79, 1585, 1707, 1708, 1710	Krings, W.	335
Kary, J.J.	1082	Kirkhope, J.	556, 1444	Krinitzsky, E.L.	524, 1649
Kashima, K.	1129	Kirton, A.J.	80	Kristiansen, U.R.	838
Kasper, P.K.	715	Kistner, A.	763	Kromp, W.	1392
Katz, L.	1265	Klauder, Jr., L.T.	1370	Krzyzanowski, A.	883
Katz, S.	1582	Klebanoff, P.S.	808	Kubbat, W.	884
Kaufman, L.	398, 1959	Klein, S.	854	Kubiak, E.J.	1195
Kaul, R.K.	1427	Klopovsky, B.A.	1503	Kucher, V.B.	895
Kausel, E.	287, 435	Klosner, J.M.	1133	Kuehn, M.	563
Kavanagh, P.	1937	Klosternan, A.L.	1512	Kugler, B.A.	1602
Kawagoe, H.	1129	Knapp, C.F.	420	Kuhlthau, A.R.	1175, 1363
Kawagoe, S.	357	Knauer, C.C.	747	Kuhn, G.F.	1229, 1440
Kawamoto, M.	58	Knauth, C.S.	360	Kukaszek, T.	533
Kawasumi, J.	148	Kneida, M.	43	Kukreti, A.R.	2025
Kaye, M.C.	928	Knight, J.	1535	Kukuchi, T.	410
Kazin, S.B.	201, 202, 203	Knight, W.A.	138	Kulin, S.A.	398, 1959
Kedrinskii, V.K.	1534	Knittel, M.R.	189	Kuljanic, E.	140
Keegan, W.B.	509	Kobayashi, A.S.	1202	Kumar, R.	1241, 1548, 1595
Keidel, W.D.	486	Kobayashi, F.	144	Kumar, S.	588
Keintzel, E.	901	Kobayashi, S.	2000	Kunieda, H.	1272
Keltie, R.F.	1426	Kobrin, M.	1463	Kunukkasseril, V.X.	127, 1442, 1481
Kennedy, A.S.	797	Koch, B.	465	Kunz, D.L.	2018
Kennedy, J.M.	922	Kochhar, R.P.	1347	Kuo, J.T.	1124
Kennish, W.J.	1289	Kochura, A.E.	723	Kuo, P.S.	549
Kenworthy, M.A.	788	Koenig, D.G.	281	Kurasz, G.	1248
Kerlin, R.L.	1818	Koenig, M.	1510	Kurz, K.	1868
Kern, E.	574	Koerner, R.M.	1769, 1782	Kuzmenko, A.A.	779
Kern, Jr., F.R.	729	Kohler, V.H.	762	Kvaternik, R.G.	948
Kershaw, R.J.	789	Koiller, J.	1724	Kwok, W.L.	110

Labra, J.J.	142	Leslie, H.D.	191	Lou, Y.K.	118
LaCroix, J.E.	1195	Lester, H.C.	839	Loup, J.	748
Ladegaard-Pedersen, A.	219	Leventhall, H.G.	722	Loushine, T.M.	557
Lai, N.W.	436	Leverton, J.W.	444	Lowery, R.L.	1016
Laidlaw, B.G.	659	Levinson, D.A.	1114	Lowrey, M.J.	125
Lakshmikantham, C.	268, 395	Levinson, M.	1872	Lowson, M.V.	543, 604
Lakshminarayana, B.	1214	Levite, U.	293	Lozier, D.W.	896
Lalanne, M.	1412, 1803	Lewis, A.B.	476	Lozinskaya, A.M.	806
Lam, F.	1389	Lewis, D.P.	940	Lucas, J.G.	1670
Lancaster, A.	389	Li, F.L.-Y.	1249	Lucco, J.E.	1762
Landl, R.	60	Liao, G.S.	141	Luco, J.E.	946, 1768, 1770
LaNeave, J.N.	1884	Licus, J.J.	742	Lüders, A.	1299
Lang, G.F.	997, 1393	Lieber, E.	70	Ludlow, J.E.	1964
Lang, M.A.	1028	Lieberman, G.A.	963	Luhrs, H.N.	1160
Lange, W.	448	Liebig, S.	1691	Luidens, R.W.	987
Langrana, N.A.	20	Liepins, A.A.	615	Luisoni, L.E.	1235
Lansing, D.L.	407, 1598, 1677	Lifshitz, J.M.	792	Luk, C.H.	266, 267
Large, J.B.	1964	Lin, S.P.	668	Lund, J.W.	1586, 1709
Larguier, R.	2030	Lin, Y.	1182	Lund, R.A.	1092, 1197
Larsen, P.K.	578, 579, 580	Lindeman, M.A.	984	Lundsager, P.	1968
Latham, D.	201, 203	Linderman, R.B.	212	Lyon, C.A.	1563
Latham, F.G.	650	Lindqvist, E.	1495	Lyon, R.H.	1346
Lauchle, G.C.	1246	Lipner, N.	1648	Lysmer, J.	783
Laufer, J.	1476	Lippmann, S.A.	1085	Lytle, R.J.	1459
Laura, P.A.A.	107, 1235	Little, J.W.	1982	McAlister, K.W.	976
Lauterborn, W.	967	Little, R.R.	1186	McCabe, W.M.	1769, 1782
Lawson, K.S.	1057	Liu, A.	372	McCartney, L.N.	1181
Leasure, Jr., W.A.	466, 1001	Liu, H.	764	McClelland, W.A.	1512
Leatherwood, J.D.	1371, 1373	Liu, R.S.-Z.	1532	McCormick, J.	2019
Lebeck, A.O.	1623	Liu, S.	1482	McCroskey, W.J.	976
Ledbetter, R.H.	924	Liu, T.M.	277	McDaniel, D.	1662
Lee, C.E.	744	Liu, W.J.J.	1397	McDaniel, T.J.	1415
Lee, C.H.	1874	Liu, Y.K.	136, 856	McDonald, D.	1484
Lee, C.K.	1697	Lizzi, F.	1265	McDonough, T.B.	1723
Lee, J.M.	1298	Llorens, R.E.	820	McDowell, E.	583
Lee, L.H.N.	1456	Lloyd, D.H.	236	McGeorge, R.	103
Lee M.U.	1230	Lo, K.K.	1991	McGhie, R.D.	1270
Lee, M.Z.	298	Lobitz, D.W.	1817	McGill, D.J.	150
Lee, P.C.Y.	550	Locher, W.E.	1579	McHenry, R.R.	1735, 1736, 1866
Lee, S.M.	1328, 1329	Lodge, C.G.	424	McKechnie, R.E.	1101, 1102
Lee, T.H.	9, 1383	Logan, D.	1156	McKenzie, J.R.	1177
Lee, Y.A.	369	Loh, H.C.	865	McKinzie, Jr., D.J.	1981, 1983
Leech, C.	860	Lomas, N.S.	858	McKisic, J.M.	961
Leendertz, J.A.	1404	Long, B.R.	659	McLean, J.D.	850
Lees, A.W.	1411	Long, L.S.	150	McMichael, J.J.	808
Lefter, J.	42	Longman, R.W.	11	McNamara, J.F.	622
Lehmann, E.J.	343, 1882, 1883	Lord, A.E.	1769, 1782	McQuillen, E.J.	820
Leingang, C.J.	1282	Lord, P.	476	McVaugh, J.M.	1706
Leipholz, H.H.E.	164, 628, 1142	Lottero, R.E.	1887	McVerry, G.H.	1491
Leondis, A.F.	1403	Lotze, A.	426	McVicar, I.	1931

Maa, S.Y.	50	Marcuson, W.F.	1649	Mei, C.	538
Macadam, J.A.	1066	Margolis, D.L.	458	Meidan, R.	950
MacBain, J.C.	272, 1926	Marietta, M.G.	1422	Meirovitch, L.	1111, 1319
Maccabee, B.	1552	Maring, G.R.	1905	Meitz, R.O.	1617
MacDaniel, D.	294	Mark, W.D.	1353	Mellen, D.M.	248
MacDonald, C.K.	305	Markenschoff, X.	550	Melnikov, B.N.	1475
MacDonald, J.A.	1093	Marks, L.E.	1034	Mels, K.D.	311
Machemehl, R.	744	Marmarelis, P.Z.	897, 898	Melvin, J.W.	600, 1303
Macinante, J.A.	1846	Marmol, R.S.	295	Mendoza, J.P.	479
Mack, R.A.	1799	Marquis, E.L.	870	Menichello, J.M.	1334
MacIsaac, B.D.	1851	Marsh, K.J.	891	Mercer, J.E.	1042, 1130
MacMillan, R.H.	472	Marsh, P.S.	632	Merchant, D.H.	361, 498
Macsween, L.	1652	Marshall, K.D.	1088, 1089	Messina, A.F.	566
Maddux, K.	301	Marshall, R.D.	1989	Metz, D.	1696
Magge, N.	328	Martin, D.J.	742	Metzger, F.B.	344, 1493
Maglieri, D.J.	414	Martin, D.W.	1418	Meyer, A.F.	341
Magliozzi, B.	344, 1493	Martin, G.C.	597	Michaelson, R.D.	1091
Magnani, E.	1295	Martin, R.	409	Michalove, R.A.	1149
Magrab, E.B.	1001	Martlew, D.L.	797	Michel, A.N.	1125
Mahabalaraja.	1240	Masri, S.F.	1203, 1791	Michellini, R.C.	618
Mahajan, K.K.	1216	Masson, A.J.	801	Michie, J.D.	1304
Mahalingam, S.	1657, 1829	Massmann, J.	1469	Michon, J.C.	149
Maher, F.J.	285, 1062	Mathes, H.B.	193	Miele, A.	1787
Mahim, S.A.	900	Mathews, D.E.	466	Mikeska, E.E.	1778
Mahrenholtz, O.	936	Mathews, F.H.	1570	Mikhitaryan, A.M.	1475
Mai, M.M.	1509	Matsuda, M.	1070	Mikolajczak, A.A.	256
Maidanik, G.	1437, 1438, 1729, 1730	Matsumoto, H.	4	Mikulka, P.J.	464, 1371
Maier, R.E.	1148	Matsuo, K.	357	Milder, G.	1109
Maiti, S.K.	7	Matta, R.K.	201, 202, 203	Miles, D.D.	457
Maizza-Netto, O.	451	Matteson, G.L.	1538	Miles, J.H.	880
Majcher, J.S.	1091	Matthew, G.K.	89, 90	Miller, B.A.	407
Majumdar, B.C.	672, 1589	Matthews, A.T.	1029	Miller, H.M.	223
Mak, S.W.	307	May, D.N.	1858	Miller, J.C.	1171
Malatino, R.E.	675	May, S.P.	1406	Miller, N.	1974
Malejannakis, G.	1510	Mayer, T.C.	1650	Miller, R.D.	1043
Malko, F.	860	Mayes, W.H.	408, 581	Miller, R.P.	1861
Mallik, A.K.	1374	Maymon, G.	108	Milligan, M.W.	1656
Malone, W.L.	1368	Mayne, R.	1140	Mills, J.H.	292
Maloney, J.G.	1498	Mayo, L.H.	1054	Milne, B.J.	1232
Malthan, J.A.	1163, 1164, 1187	Mazalov, V.N.	866	Milton, J.E.	1609
Manabe, K.	143	Mazumdar, J.	1448	Minagawa, S.	54
Manceau, J.R.	1557	Mead, D.J.	1374, 1621	Mindlin, R.D.	71, 625, 666, 669
Manhart, J.K.	926	Mechel, F.P.	1217	Minich, M.D.	541
Mani, R.	1668	Medvedev, S.V.	437	Minner, G.L.	1665, 1980
Manning, J.E.	35, 40, 731	Meece, Jr., C.E.	280	Mioduchowski, A.	974
Manos, W.P.	598	Mehlin, H.P.	359	Mira, C.	764
Mansour, A.	159	Mehner, R.	1776	Mirarefi, A.	88
March, P.A.	137	Mehra, R.K.	1878, 1966	Mirza, S.	124, 1026
Marcus, M.S.	494	Mehta, M.L.	1514	Misra, A.K.	85
		Mehta, Y.K.	1548		

Mitchell, J.S.	1773	Mukhopadhyay, V.	1208	Nelson, E.	1557
Mitchell, L.D.	248	Mulcahy, T.M.	1864	Nelson, F.C.	1179
Mitschke, M.	1733	Mulholland, K.A.	1514	Nelson, H.D.	153, 1706
Mittal, R.K.	690	Munasinghe, M.	777	Nelson, N.D.	1566
Mixson, J.S.	701	Munch, C.L.	188, 1275	Nelson, R.B.	1612
Miyamoto, T.	462	Munjai, M.L.	1300	Nemat-Nasser, S.	54
Miyao, S.	4	Muraca, R.J.	617	Nemirovsky, J.V.	866
Mizota, T.	364	Murata, R.	1659	Nepomuceno, L.X.	397, 594
Mrakar, P.F.	1211	Murayama, T.	1689	Neppert, H.	1857
Mlejnek, H.P.	1509	Murphy, E.	962	Neppiras, E.A.	1185
Modi, V.J.	85	Murphy, L.M.	210	Neshe, P.P.	398, 1959
Modig, G.	167	Murray, B.E.	1669	Ness, M.	1155
Moes, H.	1587	Murray, B.S.	729	Neubert, V.H.	815, 1413
Moiseev, N.	1214	Murtha, R.N.	1766	Newman, M.	160
Mojtahedi, S.	1744	Murthy, V.R.	1415	Neylan, A.J.	1863
Monaco, S.	804	Muster, D.	78	Niblett, T.	418
Mondkar, D.P.	181	Muszynska, A.	1096, 1097	Nicholas, J.C.	1702, 1703
Monk, M.W.	1397	Mutyala, B.R.C.	1486	Nicholas, T.	373
Montegan, F.J.	1667	Mykutow, W.J.	423, 562, 1971	Nichols, C.S.	189, 1875
Moodie, T.B.	855, 977, 1008	Myles, M.M.	1669, 1681	Niese, H.	371
Moody, N.R.	821	Myneke, H.	26	Niino, T.	253
Mook, D.T.	1817	Nachbar, W.	1610	Nilsson, A.C.	1496
Moon, F.C.	816	Nagai, K.	1450	Nishida, R.S.	1985
Moore, E.F.	1581	Nagata, O.	275	Niskodé, P.M.	484
Morales, D.A.	1641	Nagoh, T.	969	Nobile, M.A.	1848
Moravec, E.P.	1190	Nagy, D.A.	1510	Nogami, T.	1764
Moretti, P.M.	1016	Nahavandi, A.N.	630	Norin, R.S.	503
Morfey, C.L.	1229, 1344, 1440	Nair, P.S.	1954	Norman, C.D.	1842
Morgan, Jr., I.T.	1997	Nakahara, I.	4	Novak, M.	1764
Mori, E.	990	Nakai, E.	410	Novak, P.	537
Moriceau, J.	2027	Nakamura, H.	1078	Nowotarski, I.	1821
Morino, L.	1331, 1638	Nakamura, Y.	364, 1988	Nunez, H.W.	1559
Morita, T.	410	Nakra, B.C.	1385	Nuttli, O.W.	1747, 1748
Moriwaki, T.	1660	Nangia, A.K.	1595	Nycum, J.M.	261
Morris, K.G.	575	Nariboli, G.A.	1594	Nylen, W.E.	877
Morris, N.F.	1268	Nataraja, R.	688, 689	Nypan, L.J.	1932
Morris, R.D.	243	Nath, J.H.	377	Oblizajek, K.L.	1085
Morrow, C.T.	1356, 1400	Natke, H.G.	354	Oborne, D.J.	1369
Morrow, R.S.	982	Nawrocki, P.E.	1092	Ochs, J.B.	274, 1027, 1818
Mortell, M.P.	790	Nayfeh, A.H.	8, 1430, 1817	O'Connell, R.F.	566, 1473
Mosberg, W.	1531	Needham, C.E.	360	O'Connor, D.E.	719
Moseley, P.	513	Nefske, D.J.	497, 1079	Oehman, W.I.	1639
Mote, S.H.	1930	Neghabat, F.	1482	Ogawa, K.	1070
Motsinger, R.E.	1941	Negm, H.M.	1441	Ogilvie, P.L.	1715
Moulana, M.	1594	Negus, B.	832, 1800	Oh, K.P.	1934
Mow, C.C.	1379	Neiner, G.H.	676	Ohayon, R.	704
Mueller, A.W.	649, 698	Neise, W.	81, 1136	Ojalvo, I.U.	1715
Mueller, P.C.	910	Nellessen, E.	944	Okamura, H.	260
Mugridge, B.D.	1489	Nelson, D.B.	1171	Okubo, S.	804
Mukherjee, P.	133	Nelson, D.L.	940	Olejník, A.	1821

Olesen, O.V.	962	Park, W.H.	317, 1094, 1779	Pick, R.J.	1017
Olhoff, N.	1958	Parker, R.J.	1932	Pierce, A.D.	300, 332
Oliveira, C.S.	904	Parker, R.P.	815	Piercey, J.E.	1035, 1036
Ollendorff, V.F.	1308	Parkin, P.H.	710	Piersol, A.G.	1173
Olsen, B.E.	1863	Parks, C.L.	746	Pietrzyk, W.	1865
Olsen, H.A.	365	Parmelee, R.A.	433	Pilet, S.C.	1130
Olsen, S.W.	452	Parnell, L.A.	1417	Pilkey, W.D.	36
Olsen, W.	1221	Parsons, E.K.	559	Pincus, G.	1274
Olson, N.	1035	Partom, Y.	1786	Pinkus, O.	76
Olson, R.M.	315	Pasricha, M.S.	1077, 1690	Pinnamaneni, R.	284
Ono, K.	1781	Passerello, C.E.	705	Pinson, L.D.	1315
Onyeonwu, R.O.	29, 30	Patacca, A.M.	246	Pisarski, J.J.	1688
Ormerod, M.	424	Paterson, R.W.	188	Plakhov, D.D.	939
Orne, D.	1913	Patterson, J.D.	1942, 1943	Planchard, J.	1597
O'Rourke, M.J.	433	Patterson, R.W.	1275	Plett, E.G.	700
Orris, R.M.	16	Patterson, W.N.	712, 727, 728, 729, 1655	Plotkin, A.	1871
Osborne, W.C.	1432	Paul, H.S.	648	Pluzhnik, V.I.	779
O'Shea, S.	27	Paulard, M.	1412, 1803	Pnueli, D.	861
Oslac, M.J.	1945	Pauly, S.E.	1189	Pocha, J.J.	1032, 1317
Oster, K.B.	1116	Pavia, R.V.	381	Poelaert, D.H.L.	478
Ostrom, D.K.	957	Payne, K.	1719	Pollmann, E.	610
Ostrowski, P.P.	1170	Pearson, J.	1555	Polvanich, N.	95, 96
Ota, H.	1704	Pease, G.	372	Pombo, J.L.	1235
Otani, S.	773	Pedrido, R.R.	630	Pope, L.D.	1139
Otth, D.	1180	Pegg, R.J.	1099, 1493	Popkov, V.I.	232, 587, 590, 591, 592, 616
Owen, R.	1696	Pellegrin, J.D.	199	Popov, E.P.	1828
Owings, R.P.	889, 1336	Pelton, H.K.	1467, 1628	Popplewell, N.	132, 1484
Ozdemir, H.	1788	Pelz, W.	1089	Porada, W.	875
Özkul, G.A.	1247	Pendley, R.E.	1885	Porter, R.P.	191
Padilla, M.	1468	Penzien, J.	431, 905, 1834, 1835	Poryadkov, V.I.	384, 385, 546
Padovan, J.	128, 626	Peracchio, A.A.	1852	Posey, J.W.	839
Page, N.W.	1892	Perisho, C.H.	562	Potemkin, B.A.	717
Pahl, J.	350	Perkins, D.M.	208	Potter, T.E.	1361
Paidoussis, M.P.	13, 848, 1810	Perrone, A.J.	353	Pottinger, M.G.	1088, 1089
Pailly, C.	1597	Persch, H.G.	320, 1087	Poulos, H.G.	714
Painter, G.W.	403	Peschel, D.	1776	Pourrat, M.	1718
Pal, D.	216	Peters, S.	463	Pouw, A.	1895, 1896, 1897
Palaniappan, E.A.C.	1767	Peterson, A.J.	747	Powell, G.H.	181, 1990
Pallett, D.S.	1002, 1004	Peterson, R.L.	1637	Powell, J.D.	559, 970
Palma, G.E.	1330	Petiaud, C.	1470	Powers, D.R.	1159
Pamidi, P.R.	490	Petrakis, J.	1974	Prabhu, B.S.	671
Pan, K.C.	94	Petyt, M.	16, 1351	Prakash, J.	1899
Pandalia, K.A.V.	396	Peyrot, A.H.	1065	Prasad, A.S.	122
Pandit, S.M.	1658	Pfiegl, G.	218	Prasad, B.	392
Pao, Y.-H.	1379, 1756	Pfizenmaier, E.	1642	Prasad, N.M.	769
Papadakis, E.P.	1915	Phadke, M.S.	139	Prasthofer, P.H.	14
Parameswaran, M.A.	1925	Phelps, R.L.	1089	Prendergast, F.X.	1558
Parin, M.L.	221, 1488, 1803	Phillips, M.G.R.	233	Prendergast, J.D.	1721
Park, A.C.	2024			Price, E.W.	193
Park, T.	734				

Price, P.	2028	Rapp, I.H.	259	Roberts, J.W.	1, 1464
Price, W.G.	1314	Raratono, J.	1719	Robertson, S.R.	539, 1233, 1608
Priede, T.	470	Rath, A.K.	265, 621	Robinson, D.W.	1525
Przybylko, S.J.	531	Ratz, A.G.	504	Robinson, W.H.	1830
Pugatschew, A.A.	233	Rauch, F.J.	1108	Robles, L.	1058
Pugh, D.A.	1161	Ravera, R.J.	216, 409, 1176	Robson, J.D.	1, 38, 2013
Pulcher, E.T.	1976	Rawlins, A.D.	1466	Rock, T.A.	1727, 1951
Pusey, H.C.	1131	Raynesford, J.D.	1224	Rocke, R.D.	67
Putnam, A.A.	1530	Razavy, M.	192	Rodeman, R.	525
Putnam, T.W.	696, 1255	Reddingius, N.H.	1888	Roderick, J.E.	756
Putnicki, G.J.	195	Reddy, J.N.	765, 1772	Rodgers, P.W.	62
Quindry, T.L.	1518	Reddy, K.N.	1740	Rodin, E.Y.	951
Quinn, R.W.	404	Reed, W.H.	368	Roe, G.E.	1296
Rack, H.J.	1204	Reethof, G.	545	Roesset, J.M.	287, 435, 1992
Rackl, R.	1037	Regan, R.J.	1044	Roetman, E.L.	1347
Raddatz, L.A.	800	Rehfield, L.W.	279	Roger, K.L.	282
Rader, P.	1499	Reinhold, T.A.	285, 1062	Rogers, C.	1008
Rader, W.P.	1158, 1719	Reismann, H.	862	Rogers, J.L.	538
Rades, M.	1138	Reiter, Jr., W.F.	1426	Rogers, J.T.	1043
Radhakrishnan, R.	1483	Remington, P.J.	388, 732, 733, 1679, 1682	Rogers, P.F.	56
Radhamohan, S.K.	392	Rendahl, W.B.	747	Rogers, P.H.	1428
Radovcich, N.A.	566, 1388, 1473	Renirie, L.	428	Rogers, R.J.	1017
Radzimovsky, E.	88	Renka, A.R.	1712	Rogers, T.	1891
Raidt, J.B.	598	Renselaer, D.J.	1985	Rohde, S.M.	1588, 1900, 1934
Raisler, R.B.	985	Retka, J.T.	1998	Rohrmann, B.	409
Raju, I.S.	1813, 1814	Rezansoff, T.	1987	Roley, D.G.	1251
Raju, K.K.	1813, 1814	Rezek, T.W.	1362	Roman, G.W.	1031
Ramakrishna Jatra, P.	648	Rhode, W.S.	1058	Romanzi, R.A.	1513
Ramakrishnan, R.	1481, 1528	Ribner, H.S.	573	Romeo, D.J.	1307
Ramakrishnan, V.	769	Rice, E.J.	407, 837, 1944	Rompe, K.	323
Ramberg, S.E.	825, 1551, 1938	Richards, B.E.	788	Roos, R.	427
Ramirez, J.	1763	Richards, E.J.	413, 1734	Rosen, A.	686, 851, 853, 1956
Ramsey, K.A.	1146, 1399	Richards, L.G.	1175, 1363	Rosenberg, D.M.	168
Ramu, S.A.	683	Richardson, H.H.	1367	Rosenberg, G.S.	113
Ranachowski, J.	55	Richardson, M.	506, 1146	Rosenberg, R.C.	635
Rance, B.H.	447	Rickley, E.J.	404	Rosenblueth, E.	1063
Rand, D.A.	1326	Rieger, N.F.	611	Ross, A.J.	703
Randall, D.	1528	Rimer, N.	780	Ross, C.A.	1536, 1609, 1618
Raney, J.P.	1055	Rimsky-Korsakov, A.V.	1098, 1381	Ross, C.T.F.	123, 1033
Rankin, G.W.	1553	Rinehart, W.A.	208	Rossettos, J.N.	314
Rao, A.R.	176	Rinnan, A.	1165	Rostafinski, W.	1012
Rao, B.K.N.	1372, 1654	Ripperger, E.A.	1357	Rostásy, F.S.	812
Rao, B.M.	179, 348	Ritts, J.	367	Roth, G.J.	441
Rao, B.V.A.	671	Rizzo, P.C.	1157	Rottenkolber, H.	813
Rao, D.K.	1416, 1578	Roberts, C.W.	1318	Rousselet, J.	681
Rao, D.L.P.	1300	Roberts, J.B.	39, 1355	Rowley, J.W.	1560
Rao, G.V.	1461, 1804, 1813, 1814	Roberts, J.E.	340	Rowson, D.M.	647
Rao, J.S.	1802	Roberts, J.R.	751	Roy, M.K.	999
Rao, S.S.	122			Roy, R.K.	67
				Royal, A.C.	326

Rubbert, P.E.	1130	Saravanamuttoo, H.I.H.	1851	Schoonover, Jr., W.E.	1364
Rubin, C.	271	Sardyga, V.M.	532	Schroeder, E.A.	494
Rubin, S.	346	Sasaki, M.	1577	Schumacher, W.R.	876
Rudd, M.J.	388, 732, 733, 1680	Sato, K.	129, 1790	Schümer, R.	409
Ruddell, E.E.	1635	Satomi, Y.	1689	Schümer-Kohrs, A.	409
Rudrapatna, A.N.	1257	Sattaripour, S.A.	935	Schuring, D.J.	1086
Ruff, S.	890	Satter, M.A.	1902	Schutzenhofer, L.A.	796
Rugh, W.J.	1515	Saul, W.E.	1065	Schwanz, R.C.	1130
Ruhlin, C.L.	240, 1046	Saule, A.V.	2004	Schwarz, G.	558
Ruo, S.Y.	429	Saunders, D.J.	1653	Sciarra, J.J.	495
Ruppik, H.G.	1113	Saurier, G.H.	1671	Scordelis, A.C.	182, 578, 579, 580
Russell, J.B.	980	Savci, M.	660	Scott, J.N.	830
Russell, M.F.	1406	Savino, J.M.	780	Seebold, J.G.	1071, 1250
Russell, R.E.	1982	Savkar, S.D.	24, 1601	Seed, H.B.	783
Rutenberg, A.	1123, 1816	Sawdy, D.T.	380, 1942, 1943	Segel, L.	1084
Ruud, F.O.	309	Sawley, R.J.	1603	Segev, A.	1359
Ryabov, B.A.	473	Sawyer, J.W.	1023, 1234	Seide, P.	249
Ryan, J.P.	441	Scanion, R.	218	Seifert, K.	1960
Ryder, J.D.	1428	Scanlan, R.H.	1761	Seireg, A.	745
Saadat, H.	119	Schaefer, J.W.	1667	Seitelman, L.H.	608
Saari, F.	603	Schaenzer, G.	871	Sekiguchi, T.	814
Sacerdote, G.G.	653	Schaffer, M.E.	1627	Selivanov, K.N.	1100
Sachs, H.K.	2016	Scharr, R.L.	1336	Sellers, J.F.	501, 502
Sackman, J.L.	978	Scharton, T.D.	1052	Selvam, M.S.	724
Sadasiva Rao, Y.V.K.	392	Schatzle, P.R.	179, 348	Senapati, N.	731
Sadd, M.	152	Scheidt, D.C.	1196, 1568	Seneczko, M.	1072
Sadek, M.M.	138	Scherer, S.E.	1443	Sensburg, O.	426, 563, 1917
Sadigh, K.	1860	Schierloh, F.	301	Seow, B.C.	873
Sadler, J.P.	92	Schiff, A.J.	438	Sereno, T.J.	1161
Safford, F.B.	1203	Schiff, L.B.	1045	Setiawan, B.	1026
Sahoo, M.C.	374	Schlegel, R.G.	1365	Setogawa, S.	253
Saint-Hilaire, G.	239	Schlinker, R.	1476	Sevart, F.D.	565
St. Louis, L.	1265	Schlinker, R.H.	1352	Sevy, R.W.	1635
Saito, H.	1006, 1790	Schmid, W.	934	Seybert, A.F.	34
Sakurai, H.	43	Schmidt, K.G.	237	Seymour, B.R.	790
Salaun, P.	833	Schmidt, W.E.	547	Shafer, H.J.	700
Salemka, R.M.	1845	Schmiedlin, R.F.	1667	Shafey, N.A.	1616
Salmon, M.A.	1410	Schmit, Jr., L.A.	1612	Shah, R.K.	1030
Salmon, V.	1962	Schmitt, D.	415	Shahady, P.A.	1563
Samaddar, S.N.	1349	Schmitt, R.V.	1282	Shaker, F.J.	1005
Sambrano, E.	996	Schmitz, T.	1913	Shanks, R.E.	698
Samirant, M.	528	Schmugar, K.L.	1685	Shapiro, N.	183, 184, 186, 187
Samras, R.K.	72	Schneider, H.G.	1529	Sharma, S.K.	622
Sanchez-Palencia, E.	1906	Schnobrich, W.C.	1502	Sharp, R.S.	2010
Sanderson, R.	1857	Schoeberle, D.F.	761	Sharpe, H.N.	943
Sandford, M.C.	283, 1046, 1048	Schoenberg, M.	791	Shaver, J.R.	1995
Sandler, B.Z.	1434	Schoenstadt, A.L.	162	Shaw, D.E.	1157
Sankar, T.S.	725	Scholl, H.F.	701	Shaw, L.L.	1382
Sankaran, G.V.	1804	Scholz, H.	468	Shaw, M.C.	1659
Santoboni, S.	711	Schomer, P.D.	197	Shaw, R.P.	23

Shelton, M.T.	1498	Skjeltorp, A.T.	1166	Spinti, C.G.W.	742
Sherlock, J.E.	1512	Skladchikov, B.M.	911	Spokowski, A.J.	1912
Shevell, R.S.	559	Skop, R.A.	72	Spradley, L.W.	521
Shibata, A.	844, 1269	Skvortsov, V.I.	726	Srebovskii, A.I.	852
Shimizu, H.	1014	Sliwa, H.	921	Sridhar, K.	1553
Shimogo, T.	143, 253	Slocum, W.S.	1194	Sridhar, S.	1817
	1541, 1577	Slusser, R.A.	986	Srinivasan, M.G.	759
Shin, Y.W.	105	Smalley, A.J.	297	Srinivasan, P.	1358
Shinozuka, M.	1832	Smallwood, D.O.	505, 1206, 1567	Srinivasan, R.S.	1458
Shipway, G.D.	1318	Smith, C.C.	1366	Srinivasan, V.	670
Shiraki, K.	275	Smith, C.E.	377	Srirangarajan, H.R.	1358
Shishkevish, C.	655	Smith, Jr., C.V.	259	Srivastava, N.S.	588
Shivashankara, B.N.	1676	Smith, D.A.	235	Srokowski, A.J.	874
Shives, T.R.	1907	Smith, D.L.	1382	Stachiw, J.D.	1611
Shkadov, V.Y.	954	Smith, E.K.	680	Stäheli, W.	674
Shmakov, I.P.	1475	Smith, G.C.	1884	Stainaker, R.	600
Shneider, Y.G.	917	Smith, L.L.	1331	Stainback, P.C.	874, 1912
Shore, C.P.	1022	Smith, R.J.	659	Stallybrass, M.P.	1443
Shrader, J.T.	739, 740, 1297	Smith, R.R.	1875	Stanišić, M.M.	1320
Shrago, L.G.	915	Smith, R.T.	1692	Stansby, P.K.	1758, 1940
Shugar, T.A.	888	Smullin, J.I.	729	Stargardter, H.	256
Shursky, S.	575	Smutny, P.	1130	Starnes, J.H.	1049
Shyprykevich, P.	1108	Smyth, D.N.	1039	Statnikov, R.B.	401
Siddall, J.N.	1545	Sneck, H.J.	695	Stauffer, M.K.	508
Siegmann, W.L.	963	Sneckenberger, J.E.	66, 199	Stauffer, W.A.	566
Sierakowski, R.L.	1536	Snell, C.M.	205	Stavsky, Y.	82
Sigbjornsson, R.	680	Snow, R.N.	1148	Stea, W.	2028
Siljak, D.D.	955	Snowdon, J.C.	69, 262,	Stead, G.	1809
Silver, M.L.	734		274, 1027, 1818	Stearman, R.O.	284
Simandiri, S.	1590	Snyder, L.E.	256	Steele, M.M.	2017
Simitses, G.J.	259	Snyder, M.D.	1157	Steenhoek, H.F.	65
Simiu, E.	896, 1273	Snyder, W.J.	1365	Stefanides, E.J.	914, 923
Simkins, T.	218	Soedel, W.	1449, 1453	Steidle, W.	296
Simkins, T.E.	629		1454, 1486	Steinberg, D.S.	1447, 1847
Simon, E.	2024	Solberg, S.	1059	Steinbichler, H.	813
Simon, G.R.	771	Solomon, A.R.	1091	Steiner, H.	857
Simpson, A.	1128	Soltis, R.F.	1074	Stephen, R.M.	899
Sims, W.H.	521	Sommer, J.	1327, 1850	Stephens, D.G.	1174
Singer, J.	686, 851	Sommersel, B.	838	Stephens, D.H.	1067
	853, 1956	Soni, S.R.	109	Stetson, K.A.	1330
Singh, A.V.	124	Soong, T.T.	1144	Stevens, C.L.	795
Singh, M.P.	207, 1244, 1841	Sopher, R.	1700	Stevens, H.W.	713
Sinha, P.K.	265, 1899	Sorgatz, U.	318, 2015	Stevens, R.A.	1104
Sinha, S.S.	134	Southall, R.	1687	Stevens, R.C.K.	1856
Sipfle, R.E.	996	Sozen, M.A.	42, 1269, 1992	Stewart, N.D.	306
Sirbu, A.	1192	Spalding, G.R.	1877	Stewart, R.M.	1593
Sirico, J.L.	99	Sparks, N.	2019	Stiffler, A.K.	152
Sitterding, R.B.	1011	Sparrow, C.A.	279	Stikeleather, L.F.	1339
Skarecky, R.	826	Speckhart, F.H.	57, 1656	Stockdale, W.K.	209
Skinner, R.I.	1491	Sperling, A.	1786	Stockl, H.	1511

Stogoski, D.B.	475	Tabarrok, B.	1928	Tiersten, H.F.	952, 953
Stolberg, A.L.	989	Tabiowo, P.H.	1771	Ting, E.C.	231
Stone, R.W.	718	Takeyama, H.	814	Tinoco, E.N.	1042, 1130
Storment, J.W.	1467, 1628	Takizawa, H.	1836	Tirosh, J.	2000
Straayer, J.W.	361	Talbot, C.R.S.	303	Titchener, I.M.	1112
Strahle, W.C.	1676	Tallian, T.E.	1592, 1933	Tobak, M.	1045
Straight, J.W.	1323	Tam, C.K.W.	1429	Tobias, S.A.	7
Stratta, J.L.	908	Tam, W.A.	83	Tokarev, V.I.	1475
Straub, K.	1508	Tan, T.H.	1739	Tolcher, D.	1485
Stricker, P.A.	1101, 1102	Tanaka, H.	100	Tolle, G.C.	78
Strickland, W.S.	1618	Tang, D.T.	706, 1741	Tomuleseu, R.	131
Stricklin, J.A.	1460	Tang, H.M.	595	Tondl, A.	156, 157, 1178
Stuart, A.D.	1445, 1446	Tang, S.S.	1457, 1819	Tong, P.	273
Stuber, C.	461	Tani, J.	1245, 1606	Tong, P.	314
Stuff, R.	879	Tao, K.M.	751	Tonneson, J.	1586, 1591
Su, T.-C.	118	Tarasov, S.B.	652	Toplis, A.F.	1260
Subhedar, J.W.	1091	Targoff, W.P.	1342	Topper, T.H.	362
Sueoka, A.	1014	Taya, T.	822, 823, 824, 827	Tötös, K.	1868
Sugiyama, Y.	1129	Taylor, L.J.	1693	Townsend, D.P.	383, 1600
Suhoski, J.E.	251	Taylor, R.B.	1311	Trapp, W.J.	1471
Suit, W.T.	576	Taylor, R.C.	1407	Triebstein, H.	886, 1020, 1021
Sukumaran, K.	1925	Tebbs, J.D.	1567	Trifunac, M.D.	708, 1746
Sule, W.P.	1976	Tempest, W.	147		1762, 1991
Sullivan, D.F.	1179	Teng, Y.C.	1124	Triplett, W.E.	562
Summerfield, M.	700	ten Napel, W.E.	1587	Troha, W.	1801
Summerson, W.	388	Ten Wolde, T.	65	Trompette, P.	1412, 1803
Sun, C.T.	111, 1616	Teren, F.	501	Troost, G.K.	1521
Sun, J.	1219, 1430	Termuehlen, H.	610	Trout, E.M.	991
Sun, P.F.	1625	Tesar, D.	89, 90	Trummel, M.	1162
Sundararajan, C.	848	Tessarzik, J.M.	609	Tsakonas, S.	158
Susolik, O.	634	Tester, B.J.	1344	Tsay, Y.T.	1126
Sussan, N.R.	404	Thakkar, S.K.	842, 843	Tse, Y.H.	597
Sutherland, L.	194, 1037	Thaller, R.E.	1555	Tseng, K.	1638
Sutton, L.R.	442	Thau, S.A.	1903, 1904	Tseng, W.S.	1834, 1835
Sutton, P.	892	Theichen, K.-Th.	812	Tseo, G.G.	1808
Suzuki, S.I.	1455	Theisen, J.G.	429	Tsuchida, E.	4
Suzuki, Y.	260	Thiessen, G.J.	1036	Tsui, C.Y.	544
Swain, K.	1801	Thomas, C.R.	662	Tsui, T.Y.	268, 395
Swamy, S.T.N.	671	Thomas, D.L.	1411	Tucker, A.J.	1437
Swec, Jr., L.F.	103	Thomas, F.M.	102	Tuckmantel, D.L.	841
Sweet, G.	1132	Thomas, M.D.	138	Tukker, J.C.	1069
Sweet, L.M.	1367	Thomas, Jr., W.A.	1465	Tung, C.C.	1921
Swett, B.H.	1516	Thompson, D.E.	1214	Turner, M.R.	564
Swing, J.	1037	Thompson, G.O.	565	Tuttle, R.M.	1277
Sychev, Y.I.	912	Thompson, J.J.	73	Tylee, J.L.	458
Symonds, P.S.	1952	Thornton, B.S.	828	Tyler, J.M.	571
Szakovits, R.J.	1661	Thornton, P.H.	63	Überall, H.	225, 1806
Szemplinska-Stupnicka, W.	334	Thorpe, T.E.	1296	Udaka, T.	1843
Szilard, J.	1389	Tidbury, G.H.	303	Udwadia, F.E.	897, 898
Szymkowiak, E.	1156	Tieleman, H.W.	285, 1062	Ugas, C.	783

AD-A035 311

NAVAL RESEARCH LAB WASHINGTON D C SHOCK AND VIBRATION--ETC F/G 20/11
THE SHOCK AND VIBRATION DESIGN. VOLUME 8, NUMBER 12.(U)
DEC 76

UNCLASSIFIED

NL

2 of 2

AD
A035311

END

DATE
FILMED
3-77

Unruh, J.F.	161, 1431	Visnapuu, A.	1280	Warner, F.N.	1188
Urbain, G.	1718	Viswanathan, R.	794	Warner, P.C.	1433
Usselton, B.L.	1569	Viswanathan, T.	988	Warren, C.H.E.	1154
Usselton, J.C.	1569, 1573	Vlaminck, R.R.	1490	Warren, W.E.	1622
Utku, S.	1725	Vogel, S.L.	338, 339, 515, 518	Waser, R.H.	1538
Vachon, R.I.	330	Vogt, L.H.	450	Watanabe, I.	1678
Vadivelu, S.K.	769	Volin, R.H.	1517	Waterfall, A.P.	703
Vaicaitis, R.	1184, 1832	von Elmallowany, A.	1831	Waterhouse, R.V.	228, 998
Valid, R.	704, 757, 945	Von Gierke, H.E.	1338, 1651	Waters, D.M.	1262
Van, N.K.	68	VonGlahn, U.	570	Waters, J.F.	913
Van Buren, A.L.	19	VonPragenau, G.L.	1997	Watson, Jr., H.	195
Vance, J.M.	80, 326	Von Riesemann, W.A.	313, 1460	Watson, J.F.	1213
Van Der Burgh, A.H.P.	10	von Rosenberg, D.U.	856	Watson, W.	1598
VanDerlinden, J.W.	498	Von Seggern, D.	356	Wattner, K.W.	1223
Van DeVegte, J.	115, 387, 1279	Voronov, A.L.	845	Weber, H.I.	1408
VanDijk, G.M.	1975	Vorus, W.S.	1714	Weber, J.A.	1130
Van Dooren, R.	375	Vovk, A.A.	779	Weber, R.	320, 1087
VanGunsteren, F.F.	614	Vukcevic, M.B.	955	Weisman, Y.	1110
VanLoon, P.	589	Vul'fon, J.I.	646	Weiss, R.A.	743
Vanmarcke, E.H.	206	Waas, G.	287	Weisshaar, T.A.	390, 1970
VanNunen, J.W.G.	1973	Wacker, E.	196	Weissmann, S.	2028
Varatharajulu, V.	1756	Wada, B.K.	516, 1395, 1717	Weitsman, Y.	791
Vargas, L.M.	620	Wagener, J.	1020, 1021	Welch, R.E.	1694, 1695
Varner, M.O.	802	Wagland, M.A.	1418	Wells, W.R.	1965
Varygin, O.V.	939	Wagner, F.R.	601	Welton, P.J.	196
Vaterkowski, J.L.	1191	Wagner, J.M.	1981, 1983	Werner, S.D.	1732, 1861, 1862
Vaughn, J.E.	619	Wagner, J.S.	742	Wesenberg, D.L.	1923
Vaughn, Jr., V.L.	1914	Wagner, R.	1753	West, H.H.	251
vdBrink, H.	1895, 1896, 1897	Wahed, I.F.A.	949	West, M.	710
Veitz, V.L.	723, 915	Wahi, M.K.	1421, 1996	Westbrook, D.R.	1236
Veluswami, M.A.	97, 98	Waldron, H.H.	1861	Westline, P.S.	1626, 1894
Venkayya, V.B.	336	Walker, H.S.	1237	Weyer, H.	2031
Ventres, C.S.	1028, 1681	Walker, J.G.	1076	Whicker, D.	1900
Ver, I.L.	732, 733, 1669, 1681	Walker, L.A.	1632, 1633	Whitaker, H.P.	1634
Vered, M.	53	Walker, M.J.	673	Whitall, J.S.	651
Veres, R.E.	1090, 1095	Waller, H.	336, 753	Whitbread, R.E.	363
Verheij, J.W.	65	Walter, W.W.	1332	White, Jr., W.F.	586, 675
Verma, V.	1410	Walton, W.S.	1207	Whitlow, Jr., J.B.	1261
Vermeir, G.	26	Wambold, J.C.	317, 1094, 1779	Whitney, D.E.	451
Versowsky, P.E.	1898	Wambsganss, M.W.	101, 1864, 1927	Whittaker, D.M.	1225
Vickery, J.M.	1368	Wang, A.S.D.	114	Wickens, A.H.	2009
Viebrock, W.M.	721	Wang, B.P.	36	Wideawsky, A.	216
Vigander, S.	137	Wang, H.T.	641	Widnall, S.E.	369
Vigneron, F.R.	613, 938	Wang, J.T.S.	936	Wiehle, C.K.	286
Vigo, P.	1013	Wang, P.	694	Wielgus, A.	552
Vijay, D.K.	15, 84, 687	Wang, Y.S.	550	Wiener, F.	1452
Vijayaraghavan, A.	1127	Wan Moorhem, W.K.	33	Wierzbicki, T.	1115, 1922
Viner, J.G.	1304	Warburton, G.B.	126	Wilby, J.F.	1052
Vinson, T.S.	288	Ward, H.	1188	Wilcox, C.	1760
				Wilhelm, M.R.	1662, 1663

Wilken, C.A.	1985	Wu, J.J.	51, 1419	Yoshimoto, K.	144
Wilken, I.D.	1453, 1454	Wu, J.N.C.	1031	Yoshimura, T.	1988
Williams, J.L.	956	Wu, R.W.H.	391, 867	Young, J.W.	352
Williams, Jr., A.O.	1348	Wu, S.C.	1921	Young, L.C.	224
Williams, B.G.	180, 198, 410, 411, 640	Wu, S.M.	139, 1658	Young, M.E.	770
Williams, D.	147	Wu, Y.L.	115	Young, M.I.	289
Williams, F.W.	1711	Wyerman, B.R.	545	Young, R.K.	1366
Williams, G.	603	Wynne, E.C.	1972	Young, T.C.	1686
Williams, R.B.	1546, 1547	Wyn-Robers, D.	1931	Yousri, S.N.	1414
Williams, V.	1949	Wyskida, R.M.	1662, 1663	Youssef, N.A.N.	1484
Williamson, H.J.	1302	Yablonskiy, V.V.	401	Yu, J.C.	351
Williard, W.A.	1907	Yakovlev, K.B.	473	Yu, R.	176
Willmert, K.D.	1361	Yamada, K.	1266	Yumshtyk, M.G.	918
Wilson, E.L.	707	Yamaki, N.	1450	Yung, C.	767
Wilson, G.J.	1444	Yamamoto, T.	148, 377, 969	Yutani, T.	1790
Wilson, G.P.	920	Yamanaka, N.	1678	Yuzawa, A.	824
Wilson, H.B.	942	Yamataka, T.	358	Yuzawa, M.	656
Wilson, R.R.	1411	Yancey, C.W.	1989	Yuzefovich, A.P.	806
Winget, J.M.	1480	Yaneske, P.P.	1632, 1633	Zalesak, J.	499, 500
Winn, L.W.	1212	Yang, A.W.	1220	Zapotowski, B.	736, 1295
Wise, D.A.	1103	Yang, J.-N.	480, 947, 1471	Zara, J.A.	1644, 1173
Withers, J.G.	1016	Yang, R.T.M.	1919	Zaretsky, E.V.	383, 1600
Witmer, E.A.	391, 867	Yang, T.Y.	847	Zaripov, R.G.	1604
Wittmeyer, H.	1780	Yao, J.T.P.	176, 438	Zaschel, J.M.	1544
Wolf, Jr., J.A.	497, 1079	Yashaev, I.L.	806	Zemell, S.H.	1757
Wolf, R.J.	991	Yasuda, K.	969	Zetkov, G.	1294
Wolf, T.D.	1362	Yates, Jr., E.C.	1969	Zienkiewicz, O.C.	1727
Wong, H.L.	708, 1762, 1991	Yates, R.	180, 198, 410, 411	Ziolkowski, Z.	534
Woo, H.K.	1237	Yee, H.C.	760	Ziperman, H.	929, 930
Wood, J.H.	1742	Yelezov, V.G.	400, 401	Zipfel, P.H.	1967
Woodard, H.S.	1672	Yen, D.H.Y.	1238, 1819	Ziv, M.	48, 644
Woodfin, R.L.	1566	Yenenkov, V.G.	1475	Zobrist, G.J.	1145
Woodward, B.	463	Yetman, Jr., W.R.	868	Zolotas, A.B.	941
Woodward, R.P.	1670, 2005	Yeung, R.	574	Zomotor, A.	324
Wooten, R.D.	345	Yildiz, M.	1531	Zsolcsak, S.J.	1705
Wormley, D.N.	527	Yim, S.J.	1413	Zuckerwar, A.J.	1784
Worster, J.	832, 1800	Yokel, F.Y.	1989	Zukoski, E.E.	1599
Wortman, J.D.	116	Yonetsu, S.	255	Zurnaciyan, S.	1396
Wray, W.O.	780	Yoo, T.S.	906	Zuziak, R.J.	1110
Wright, D.V.	1433	York, R.E.	1672	Zwaan, R.J.	427
Wright, S.E.	605, 1312	Yoshida, K.	143, 1541	Zwick, J.W.	1941
		Yoshida, Y.	58		

- A -

Absorbers (Equipment)										Acoustic Liners													
872				25						1430		691		1283		1665		1667					
Absorbers (Materials)										Acoustic Linings													
870 131				1778						1431		692		543		544		545 1466 837 678 679					
1630										1961		1942		873 1944 1945				1598 739					
														1943				839					
Accelerometers																							
370 62				655																			
				1535						Acoustic Measurement													
										1000		881 1002 1003		654 1405		656 147		1199					
Acoustic Absorbers										1090 1001 1562 1004 876 987 1909													
				1465						1440		2012				1066 1777							
Acoustic Absorption										Acoustic Measuring Instruments													
1230 131 692				1514		25		656 837 678 679												807			
1280 691 1912								876 1667 1778 1959															
1630								1316															
1960								1546		Acoustic Properties													
										1630 1941				1906 1217		1769							
										1670													
Acoustic Detection										Acoustic Resonance													
				1155		1546												1280 32					
Acoustic Diffraction										Acoustic Response													
				1124														1133 1715 1317 1438					
Acoustic Energy Decay																				1153 1775 1437			
1603																							
Acoustic Excitation										Acoustic Scattering													
1032				1414		1246		1889		1552		624 645 196		27 1548 1529									
				1474								1124 965 1246											
												1466											
Acoustic Fatigue										Acoustic Signatures													
1200								1228		30		183 184 185		186 187		29							
Acoustic Holography																				746		479	
1882 343 244 245						247																	
1883										Acoustic Spectra													
Acoustic Impedance										880 1312													
190 691				653 1944 1035 1036		678 679		Acoustic Techniques															
1630 1891						1169		1920 1781 1782 1553						1627									
Acoustic Insulation										Acoustic Tests													
1381				894		26		1068 709		650 511		1104 795 986		1137 1198									
1831										801		1394 1985 1986		1407									
												1984		1977									

Abstract Numbers:	1-159	160-332	333-486	487-623	624-751	752-948	949-1117	1118-1318	1319-1503	1504-1721	1722-1871	1872-2031
----------------------	-------	---------	---------	---------	---------	---------	----------	-----------	-----------	-----------	-----------	-----------

Volume 8

Issue	1	2	3	4	5	6	7	8	9	10	11	12
-------	---	---	---	---	---	---	---	---	---	----	----	----

Active Isolation												
560	401	562	563	564			1048					
	1251	1632	1633									
	1631											
Aerial Explosions												
		1163	1164									
Aerodynamic												
			554									
Aerodynamic Characteristics												
1040	1051	302				1937						
		1112										
Aerodynamic Damping												
			285									
Aerodynamic Excitation												
	541				786	887	1239					
Aerodynamic Loads												
1050		1044			417	348	179					
					427	428	429					
							829					
Aerodynamic Noise												
		1754		776		1098						
Aerodynamic Response												
	833		415	576			619					
Aerodynamic Stability												
	241		1045	826								
	331											
Agricultural Machinery												
		1994	1655			7						
Air Bags (Safety Restraint Systems)												
770	931	932	933			557	468					
						1307						
Air Blast												
						1648	659					
Airborne Equipment Response												
		1555	1156									
			1396									
Air Compressors												
			755									
Air Conditioners												
Air Conditioning Equipment												
		1671		594								
Aircraft												
1040	241	162	283	244	415	16	887	1148	559			
1130	281	282	883	514	565	576	1047	1638	879			
1470	441	452	1043	704	585	606	1147	1968	1039			
	691	562	1363	794	1045	1526	1967		1519			
	871	692	1473	834	1175	1966			1639			
	1041	1042	1973	884	1965	1986						
	1051	1362	1833	1044	1975							
	1471	1382		1174	1985							
		1402		1364								
				1474								
				1634								
				1914								
				1974								
Aircraft Cabling Areas												
							536					
Aircraft Engines												
280	501		1593	1984		326		328				
	531					416						
Aircraft Equipment												
						1573						
Aircraft Noise												
180	201	172	183	174	185	186	167	168	409			
410	351	202	203	184	195	406	187	188	569			
570	411	342	403	194	405	696	407	198	639			
640	571	402	413	204	1055	1036	567	408	699			
880	771	412	573	344	1255	1056	697	568	1259			
1260	881	572	693	404	1475	1256	877	698	1479			
1261	1151	882	1053	414	1525	1476	987	768	1979			
1960	1521	1642	1643	694	1885	1976	1057	1258				
	1641	1982	1983	774	1856	1257	1478					
	1981	1852		1054			1477	1888				
				1254			1977	1978				
				1524								
				1734								
				1884								
Aircraft Propellers												
				1312	673		607	408				
					1493							
Aircraft Seats												
						705						
Abstract Numbers												
1-159	160-332	333-486	487-623	624-751	752-948	949-1117	1118-1318	1319-1503	1504-1721	1722-1871	1872-2031	
Volume 8												
Issue	1	2	3	4	5	6	7	8	9	10	11	12

Aircraft Tires
742

Aircraft Vibration
560 701

284 566 419
464 449
1969

Aircraft Windows

1636 1637

Aircraft Wings

420 421 422 423 424 425 426 417 418 429
560 561 702 563 564 786 427 428 1049
880 1971 1052 703 886 577 1048 1469
1050 1972 1917 1519
1970 1832

Air Cushion Landing Systems

527

Airfoils

280 1021 1563 776 1698
1020 1601 976

Airframes

1252

Airports

172 194 195 1629
1262 1979

Aluminium

58

Ammunition

1163 1164 1165 1166 217 238
1167

Amplification

1642

Amplitude Analyses

152

Amplitude Data

1771 1745 1746

Analog Computers

1207

Analog Simulation

1 753 487 1069
921 1207 1199
1421

Analytical Methods

1500 1321 1522 1318

Anemometers

808

Animal Response

1645

Anisotropic Properties

777

Anisotropy

1924 128

Antennas

613 478 659

Anthropomorphic Dummies

1480 991 1303 177 338 339
1361 317 929
467 1779

Antifriction Bearings

254

Approximate Methods

1235

Approximation Methods

10 1121 763 954 1325 7 119
1441 1435 37
107
377
1097

Arches

842 843 259

Arrays

613

Asymmetry

1713

Asymptotic Approximations

1452 754 855

Abstract Numbers: 1-159 160-332 333-486 487-623 624-781 782-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue 1 2 3 4 5 6 7 8 9 10 11 12

Attitude Control Equipment
942

677
1997

- B -

Automated Design
1990

635

Automated Testing

1918

Automated Transportation Systems
1722

Automobile Bodies
1000

Automobile Engines

1078

Automobiles

981 602 303 1544 1366 468 1079
1301 973 738 1869
1543
2013
1733

Automobile Seat Belts
600

Automobile Seats
600 322

Automobile Tires

320 321 323 466 318 319

Automotive Transmissions

385 386 299

Autoparametric Response

154 155

Axial Excitation

1451 13 1005

Axial Force

142 75 1706

Axiallysymmetric Vibrations

1451 685 228 109

Balancing

1586

Balancing Techniques

1702 1703 995 609

Ball Bearings

1212 1933 325 148 1799
1932

Balls

97 98

Bars

71 822 253 824 376 667 1408 669
1462 753 1784 666 827 1409
1572 823 977
1143 1957

Beam-Plate Systems

1793

Beams

660 51 22 663 374 375 1316 537 538 50
680 451 1412 1123 384 385 1416 657 658 249
1210 661 1922 1413 814 815 1576 817 818 659
1420 821 1792 1513 1414 1005 1626 997 1578 819
1740 1211 1573 1574 1025 1786 1017 1788 859
1790 1791 1923 1694 1415 1577 1119
1894 1575 1209
1924 1695 1279
1794 1409
1814 1419
1679
1789

Beams (Supported)

75

Beams (Supports)

250 74

Bearing Response

1589

Bearings

1010 611 1592 634 326 1737 328 439
741 1584 1009

Abstract Numbers: 1-189 180-332 333-486 487-623 624-751 752-848 849-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Bridges (Structures)
1481

1646 1267 1268
1647
1987

Bubble Dynamics
1552

1185 967

Buckling

1211 2 865

Buildings

170 581 132 433 44 895 176 567 708 169
480 621 432 1063 404 905 286 707 898 569
710 711 632 1273 894 706 897 899
900 1271 1742 1483 904 896 1069
1270 1991 1004 1066 1989
1520 1841 1384 1836
1840 1484

Bumpers

1081 1082 1083

Buoys

641

Buses

464

- C -

Cables

1210 1551 825 826 59
1796 229

Cables (Ropes)

1930 251 72 1583 1797 378
641 1422
1931

Cable-Stiffened Structures

1268

Calibrating

61 1774 1518 649
651

Calibration
990

Cams

90 91 95 96 487 89
1010

Camshafts

91

Cantilever Beams

1200 22 663 664 85 936 1417 1208 539
1410 252 1804 665 1926 1787 1418 789
662 1005 1209
1925 1579
1785

Cantilever Plates

272 1816

Cantilever Rods

1927

Cantilevers

1123

Cargo

1540 1539

Cargo Transportation

529

Catenaries

1797

Cavitation

974
1534
1664
1854

Cavitation Noise

913 967 968

Cavities

1597

Cavity-Containing Media

1827 48

Abstract Numbers: 1-159 160-332 333-486 487-823 824-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Cavity Resonators
1351 32 1194 1185 966 497
1382

Ceramics
55

Chains
1014

Chatter
1660 301 56 1999
1661

Chimneys
1182 1216 1418 399
689

Circuit Boards
1447

Circular Cylinders
60 23 86 687 1758
1427

Circular Plates
110 1811 1442 1814 127 109
120 1812 1817 1619

Clocks
721

Coatings
220

Coefficient of Friction
1300 647 88

Coherence Techniques
34

Collision Research (Aircraft)
1993 705

Collision Research (Automotive)
600 601 322 933 314 515 1306 177 338 339
930 931 602 1303 1304 1305 1736 467 518 929
1480 991 872 1753 1694 1695 1866 1307 738
1361 932 1735
1881

Collision Research (Railroad)
921

Columns
133 1804 1805 1007 908

Columns (Supports)
250

Combustion Excitation
193

Combustion Noise
700 1071 453 1754 775 596 1689
1250 593 1676
1530 2026

Commercial Aircraft
410 201 202 183 184 185 186 187 1258
203 697

Commercial Transportation
530

Compaction Equipment
434

Component Mode Analysis
1644 2025

Component-Mode Synthesis
500 346 347 948 499
516 517
1717

Composite Beams
820

Composite Materials
790 403 175 1537 849
1755

Composite Structures
541 54 626 1827
966
1616

Compressor Blades
1672 833 224 256
1593

Abstract
Numbers: 1-189 180-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issues: 1 2 3 4 5 6 7 8 9 10 11 12

- D -

Damage Prediction

254 1225 567
904 1617

Damped Structures

361 752 274 115 1279
871 1222
1872

Damped Systems

1375

Damper Locations

57

Dampers

660 43 115 558
1180

Damping

440 481 482 483 125 106 77 1179
610 561 1322 713 485 1446
1281

Damping Coefficients

671 288 1589
1591 1588

Damping Effects

1704 1705

Damping Values

980 57

Dams

170 1781 1842 1843 437 169
1649

Data Display

981

Data Presentation

980 1163 1164 1258

Data Processing

530 881 924 1395 697 1138 579
1311 1094 1187 1188
1174

Data Reduction

982

Decay Laws

962

Density (Mass/Volume)

1575

Design Information

957 459

Design Procedures

1696

Design Techniques

2020 1081 742 1093 454 425 1216 7 798 879
832 1274 635 1556 257 1248 919
1082 1944 885
1382 1225

Detectors

993

Diagnostic Techniques

650 592 1223 1075 1227 379
1650 982 1773 1265 1907 439
1920 729
1389

Diesel Engines

1690 2012 453 914 1686 1077 588 389
1687 1688 1689
1919

Difference Equations

760 753

Differential Equations

755

Diffuse Field Measurement

998

Digital Computation

503

Digital Simulation

510 501 22 513 144 505 316 507 158 509
521 502 633 504 745 506 767 508
611 512 514 2015 746 1197
751 642
1832

Abstract Numbers: 1-150 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Dynamic Stiffness

140 743

Dynamic Structural Analysis160 181 173 165 516 1727 298
761 903 756**Dynamic Synthesis**

90 1434 487 89

Dynamic Systems760 1122 955 337 1878
1435 1127**Dynamic Tests**580 1501 382 63 734 215 736 867 578 579
600 742 813 1165 1016 1007 808
792 983 1395 1086 1737 938
1202 1586**Dynamic Vibration Absorption (Equipment)**262 1224 1848 69
1704

- E -

Ears

293 1264 1645 1406 1468

Earthquake Damage170 211 42 773 44 1116 1007 438 169
210 902 1743 1836 908
900 1992
1742**Earthquake Prediction**

1750 1751

Earthquake Resistant Design

343 905

Earthquake Resistant Structures170 41 622 43 844 215 706 1647 169
1740 1721 902 903 904 1805 1386 209
1830 1741 1862 1646 899
1269
1649
1839**Earthquake Response**

1744 1837 1838

Earthquakes480 901 52 783 64 45 46 437 208 979
971 1203 524 355 1186 897 288 1249
1533 904 435 1196 907 1268
1843 914 1745 1746 1117
1267**Edge Effect**

1143 1956

Eigenvalue Problems490 1111 333 1825 948 1319
1510 1141 1333 1128
1598
1808**Eigenvalues**

952 1324 1026 978

Elastic Foundations310 1771 142 154 75 1006 818 59
1870 384 385 1096 1209
665**Elasticity Theory**1241 1183 626 1008 1129
666**Elastic Media**

648

Elastic-Plastic Properties

1923 1786 87 1788

Elastic Properties10 71 823 6 628 669
1953 1796 648
1783**Elastic Waves**520 951 352 193 1124 35 1756 787 1218 189
840 1622 1013 1904 545 1757 999
1630 1903 555 1379
645 1739**Elastohydrodynamic Properties**

1900 1015

Abstract Numbers: 1-150 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Elastomers					Engine Noise									
1180	1132			1428	740	171	202	203	34	1665	296	987	168	1689
	1282				1980	201	2012	453	344	1885	596	1667	388	
Electrical Machines						571		603	454		1686	1687	408	
				957		1261		1053			1856		588	
								1283					1688	
Electric Power Plants					Engines									
	102	1893	1805	137 438 399				502		295				
				207										
Electrodynamic Shakers					Engine Vibration									
	504	505						453		1865		417 1078	739	
												1657		
Electrohydraulic Shakers					Epoxies									
			1566					973						
Electromagnetic Excitation					Equations of Motion									
			816		10		312	663	474	1505	1236		308	789
Electronic Instrumentation					1320		1422	1323					1928	1609
				1847	1700			1713						
								1723						
Electronic Test Equipment					Equipment									
	1400												1038	
Elevated Railroads					Equipment Mounts									
	731		734					261			1846	2027		
								1931				1847		
Enclosures					Equipment Response									
		873		1809				261	1482	1224	1516	37	1558	1309
												1887		
Energy Absorption					Equivalent Linearization Method									
	1740	1171	1993	1305 1356										
	1830													
Energy Dissipation					Equivalent Linearization Technique									
		622	263											
				1179							1725			
Energy Methods					Error Analysis									
	1620	161		1797										
								90	1391				689	
Energy Transfer								1890						
				587										
Energy Mounts					Exact Methods									
			1494	328						625			1119	
					Exact Point Speed Influence Coefficient Method									
													609	

Abstract Numbers: 1-159 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Exhaust Systems

699

Failure Analysis

972 673
982 1223

1355

1618 1309

Expansion Joints

1646 1647

Fans

280 81 1312 243 224 455 256 1667 1488 1489
380 541 1852 1073 2004 605 456 2007 1668 1669
830 1011 1213 755 1136
1670 1291 1853 1885 1666
1671 2005 1936
1961 2006
1801
1851

Experimental Data

570 81 52 703 304 315 56 67 88 469
580 411 282 713 824 405 526 77 698 579
830 701 582 933 864 575 546 97 858 619
850 702 1163 924 715 706 127 868 709
742 1304 736 227 928 749
776 467 1058 899
907
1717

Fast-Fourier Transformation

335

507

Experimental Results

280 351 1493 874 25 26 887 119
410 391 359
461

Fatigue

1181 224

Experimental Safety Vehicles

602 467

Fatigue Life

1600 1471 1592 383 1424 1545
1543 1544 1975
1933 1624

Explosion Detection (Nuclear)

779

Fatigue (Materials)

441 362 176 1248
741

Explosion Effects

860 132 1894 246
1752

Fatigue Strength

2020

Explosions

781 782 1163 1164 1165
972

Fatigue Tests

1200 1392 1463 1266 58
1932 1298
1832 1568

Explosives

217 238

Fiber Composites

792 1924 1755

External Damping

662 377

Fibres

236

Finite Difference Method

87

Finite Difference Techniques

1511
391

Facilities

42

Abstract Numbers:

1-160 160-332 333-486 487-623 624-751 752-848 849-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue 1 2 3 4 5 6 7 8 9 10 11 12

Finite Difference Theory

1220 841 555 116 777 1598 1029
1820 1191 436 1987
1231 786

Finite Displacement Method

132

Finite Element Analysis

540

Finite Element Technique

110 391 272 123 314 15 16 37 128 499
230 431 492 173 494 165 436 287 218 549
390 831 622 193 854 495 1436 307 498 1079
500 981 772 273 1124 945 1526 667 888 1469
630 1351 922 493 1264 1315 1706 687 948 1509
1080 1411 1412 613 1444 1505 1876 767 1378 1579
1220 1461 1842 643 1694 1625 2026 847 1508 1619
1470 1611 863 1874 1685 1766 867 1558 1879
1510 1951 1033 1934 1695 1017 1598 1809
1890 1811 1333 1804 1875 1357 1638
1820 1803 1814 1507 1728
1860 1813 1727 1788
1870 1843

Flexible Couplings

295

Flexible Foundation

151 133 1704

1579

Flexural Vibrations

120 551 92 1813 94 75 376 658 289
250 1811 1232 384 375 396 1949
1792 804 1595 936
1755 1416
1815 1826

Flight Vehicles

279

Floating Ice

1350

Floors

1064 1995

Floquet Theory

848

Flow-Induced Excitation

1810 681 1864

Flow-Induced Vibration

1684

Fluid-Filled Containers

154 155 857 618 1379
275
305
365
945
1955

Fluid-Film Bearings

1870 1585 1707

Fluid-Film Damping

80 1705 2029

Fluid Hammer

105

Fluid-Induced Excitation

60 31 13 74 105 86 17 18 119
610 101 103 364 365 226 137 548 229
1030 631 113 544 555 836 227 618 849
1381 1133 704 835 1446 737 848 1379
1581 1604 1215 1596 1017 858 1549
1901 1445 1806 1597 968 1599
1605 1018 1939
1675 1678 1949
1685 1808

Fluid-Induced Vibrations

112 73 394 106 118

Fluid Mass

1377

Fluids

228

Flutter

240 331 282 283 284 425 256 417 418 419
280 421 422 423 354 565 566 627 828 629
390 561 562 563 424 665 606 847 1048 1049
420 681 1022 633 554 1046 1047 1108 1209
440 1331 1272 1023 564 1296 1387 1118 1969
850 1601 1472 1473 664 1506 1917 1128
1970 1971 1572 884 1388
1801 1972 1234 1638
1954 1988

Abstract Numbers: 1-159 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Foams1662 1993 294
2002**Follower Forces**

1804 85 1506

Footings435 287 908
1765**Forced Vibrations**1790 301 112 1143 1014 1235 86 107 489
1821 252 1443 626 1097 899
1441 1322 1613 1006 1957 949
1442 1973 1326 1449**Forging Machines**

28

Foundations590 1903 734 946 587 1768
1494
1904**Four Bar Mechanisms**

92

Fourier Analysis

1146 47 1399

Fourier Series

130

Fourier Transformation

1462 1095 506 1578

Fourier Transforms

1197

Fracture Properties

1511

Framed Structures

680 41

Framed Tube Technique

1839

Frames1510 1741 1222 133 844 87 258
773 537 538**Free Piston Dampers**

68

Free Vibration1481 392 1143 1794 165 86 277 1118 129
1951 1973 1814 265 1616 1957 1238 1929
1615 1458
1958**Freight Cars**741 735 147 958
597
1737**Frequency Analyzers**

997 1399

Frequency Domain

1866 1878

Frequency Meters

242

Frequency Response320 912 1483 935 146 1087 1138 1919
1582 1605**Friction Excitation**

911 1623 647

Frozen Soils

713 288

Functions (Mathematics)

859

Fundamental Frequency1414 1435 1027
1247**Fundamental Mode**

1026

Furnace Noise

1530

Fuses (Ordnance)

975

Abstract Numbers: 1-150 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031**Volume 8****Issue:** 1 2 3 4 5 6 7 8 9 10 11 12

- G -

- G -									
					Graphic Methods				
					410	635	1387	1138	
						1025	1617	1388	
Galerkin's Method									
	542	1354		107	1429				
	1142	1804							
	1802								
Gas									
	50								
Gas Bearings									
	672		76	77	1589				
					1709				
Gas Turbine Blades									
	220								
Gas Turbines									
	700	691	692		1676	797	678	679	
						1557		699	
						1677			
Gearboxes									
	381	382							
Gear Noise									
	171		344						
Gears									
	260	383	384	385	386		88	299	
	1010	443	1434	845	546		248	439	
	1600	1433							
Geometric Effects									
				1796					
Geometric Imperfection Effects									
	130				1218				
Girders									
	580			1646	1647	578	579		
							1249		
Glass									
			26						
Gliders									
	1472								
					Grass				
						1035			
					Gravity Effects				
						150			
					Green Function				
							1877		
					Grinding Machinery				
						634			
					Ground Effect Machines				
						574	1295	316	458
						1294		736	
					Ground Motion				
					1751	52	1743	64	45
							1863	524	1745
								46	1747
									968
									1748
					Ground Shock				
						1163	1164		526
					Ground Surface				
							1035	1036	
					Ground Vehicle Noise				
						771			
					Ground Vehicles				
					1340	1092	1913	934	445
							2013	1174	925
								2014	935
								2015	
									178
									1298
									1868
					Ground Vibration				
						1732	1384		
					Guard Rails				
						1093	1304		
					Guideways				
					460	1631	312		459
					Gun Barrels				
									218

Abstract Numbers:	1-150	160-332	333-486	487-623	624-751	752-948	949-1117	1118-1318	1319-1503	1504-1721	1722-1871	1872-2031
Volume 8												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Gunfire Effects
492 493 695 1566 1207
1172 1173 1635

Gyroscopes
1070 1324

Gyroscopic Excitation
1713 1706 149

Gyroscopic Vibration Absorber
66

- H -

Half Plane
648

Half-Space
644 1006 1757

Hamiltonian Functions
663

Hamiltonian Principle
1872

Hardened Installations
583 216 1648

Harmonic Analysis
182 1544 375

Harmonic Excitation
250 1612 836 1127 969
1790 1596 1939

Harmonic Response
1412 126 487
886
1616

Harmonic Waves
54

Head (Anatomy)
1263 856 888 889
1753 1059

Heat Exchangers
1030 31 86 1017 1018 1939
101 106
1901 1016

Helical Gears
1600 383

Helical Springs
1462 869

Helicopter Engines
326 439

Helicopter Equipment
1517

Helicopter Hoists
716

Helicopter Landing
1277

Helicopter Noise
443 344 1275 746 188 369
444 1365
604
1844

Helicopter Rotors
1312 1313 1275 1276 2018 829
1712 1099

Helicopters
290 441 442 493 584 495 586 557 289
440 492 1993 585 937 519
1650 605
715
1365

Helicopter Vibration Effects
1365

Helmholtz Resonators
1193 1486
1553

Abstract Numbers: 1-159 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Hemispherical Shells	1608	Human Factors Engineering	1034	515	718
High Frequency Excitation	1588	Human Hand	1065		
High Frequency Resonance Technique	254	Human Head		136	
High Frequency Response	861	Human Organs		486	
High Speed Transportation	1541	Human Response	350	291	292
	143		430	1061	1262
	1631		450	1341	1302
High Speed Transportation Systems	736		450	1371	1362
	458		1340	1651	1372
Highway Transportation	1881		1370	1652	1364
Hinges					1654
	629				1884
Hoists	11				1964
	12				1994
Hole-Containing Media	1240				
	544				
Holes	1891				
Holographic Techniques	813				
	1404				
Honeycomb	1993				
Honeycomb Structures	1032				
Hopkinson Bar Technique	373				
Hospitals	1721				
	42				
Household Appliances	723				

Abstract Numbers:	1-159	160-332	333-486	487-623	624-751	752-948	949-1117	1118-1318	1319-1503	1504-1721	1722-1871	1872-2031
Volume 8												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Hysteretic Damping
661 1763 1584 1495 1007
1764 1127
1767

Industrial Noise
892

Inertial Forces
1690 83 85 1077
1913

Inflatable Belts
930

Inflatable Structures
770 933

Infrasonic Frequencies
61

Inhomogeneous Sphere
1757

Initial Deformation Effects
550 851 114 1416 1928
1506

Instrumentation
534

Insulation
136

Integral Equations
333

Integral Transformations
626

Interaction: Fluid-Structure
1184 1548

Interaction: Propeller-Rudder
158

Interaction: Rail-Wheel
1680 731 312 733 597 1679
1681 732 1683
1682

Interaction: Soil-Structures
1770 431 1902 1383 44 435 436 287 288 1029
1860 971 1762 1903 1904 1186 708
1991 1743 1744 1386 2028
1761 1764 1766 1768

Impact Dampers

67

Impact Load Prediction
1720

Impact Pairs
97 98

Impact Response
820 1263 1874 537 1168
1968

Impact Response (Mechanical)
1611 1574 136 1357 1618

Impact Shock
1171 575 136 527 598 1109
1535 1636 1637

Impact Testing
1190 1402 1204

Impact Tests
930 1031 1242 373 735 1536 97 99
1570 1303 1285 127 929
1019
1559

Impedance
1591 1494 1679

Induction Motors
1692 1693

Industrial Facilities
1250 891 1962 893 1346 1467 1628
1530 1071 1963

Abstract Numbers: 1-150 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Interaction: Structure-Fluid					- J -							
630	1551	494	175	137	1549							
1550				1607								
Interaction: Structure-Medium					Jet Aircraft							
				1428	570	1221		1475	1046	697	1258	699
								1476				1479
Interaction: Vehicle-Guideway					Jet Engines							
		316		459	700	221	1283	694	1056	327	1478	
						571	1343		1666	1477	1488	
Interaction: Wheel-Pavement							1803					
1300		315			Jet Noise							
						1642	1343	1344				
Interaction: Wheel-Tire						1852						
			1867									
Interface: Solid-Fluid					Joint Compliance Extraction Technique							
			787			1498						
Interface: Solid-Solid					Joint Force Analysis							
			759			93						
Interferometers					Joint Relaxation Technique							
	1404					1829						
Internal Combustion Engines					Joints							
	682	723		1486	1487	1918	1179					
	1282											
Internal Damping					Joints (Junctions)							
	662	164	665	377	1768	1789	1990					
		664	1755		Journal Bearings							
					670	671	672	1934	1585	1586	1587	78
Internal Friction					1710	1588						
	234											
Internal Pressure												
	392		1455									
Internal Resonance					- K -							
		155										
Iteration					Kantorovich Method							
1320		1063	814		1232							
		1753										

Abstract Numbers:	1-150	160-332	333-486	487-623	624-751	752-948	949-1117	1118-1318	1319-1503	1504-1721	1722-1871	1872-2031
Volume 8												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

- L -

L										Launchers			
										720	1497		
Lagrange Equations of Motion										949	Launching Response		
											51 1332	945 1716	
Laminates											801		
110	111	1822	1023	54		1616	1827	1848	789		811		
790										Launch Vehicles			
										620			
Landing											Layered Materials		
										575	527	1109	
Landing Craft											777		
										574	575		
Landing Fields											Leading Edges		
										924	786		
Landing Gear										Least Squares Method			
1421		1253		575		1532							
Landing Impact										Lifting Surface Theory			
1470						617	158						
Landing Pads										Limiting Performance			
										1277	36		
Landing Simulation										Linear Programming			
										1039	36		
Landing Simulator										Linear Systems			
1403										1850	763	95	1849
Laplace Transformation										Linear Theories			
											143	1325	
											1953		
Large Amplitudes										Liquid Filled Containers			
1242											1378		
Lateral Response										Liquid Propellant Rocket Engines			
311											1113		
Lateral Vibrations										Locomotives			
											311	1865	
										Longitudinal Response			
										248	72		
Lathes											376 377		
											1006		
										726	Longitudinal Vibrations		
											94		

Abstract Numbers:	1-159	160-332	333-486	487-623	624-751	752-948	949-1117	1118-1318	1319-1503	1504-1721	1722-1871	1872-2031
Volume 8												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Longitudinal Waves

8
1008

Lubrication

1010 1933 984 1015 1226
1900 1934

78 99
1009
1899

Lumped Mass Method

1925

Lumped Mass Models

1926

Lumped Parameter Method

1310 92 14 1727
1144

Lyapunov Approach

1722

Lyapunov's Functions

1243 628

- M -

Machine Foundations

2003 1274

Machine Noise

299

Machinery

300 1773 957
1850

Machinery Components

1015

Machinery Noise

171 232 803 797 398
771 1072 913 768
1571

Machinery Vibration

590 591 232 616 587 398 299
911 592
912
992

Machine Tools

140 301 724 725 56 918 139
1660 726 1658 589
919
1659
1999

Machining

138 1659

Macroelement Method

1990

Magnetic Tapes

1737

Manipulators

451

Marine Engines

1077 329

Marine Propellers

1214 2008

Marine Rudders

941

Marine Transportation

1101 1102

Masonry

899

Mass-Beam Systems

1794

Mass Matrices

1330 1033

Mass-Spring Systems

1724 1376

Abstract 1-159 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031
Numbers:

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Material Damping
1401 403 274 1768
1374

Materials Handling Equipment
1540 451

Mathematical Cables
59

Mathematical Modeling
1730 1526 1967 1368 1729
1876

Mathematical Models
30 91 312 53 34 95 96 17 18 19
60 311 322 143 44 115 136 177 28 589
430 531 492 293 144 295 146 527 88 889
1410 621 632 383 284 455 226 597 98 899
1490 631 1152 493 294 515 416 607 278 1079
1600 731 1472 613 304 585 586 967 318 1129
1720 961 1822 723 314 705 766 1037 448 1289
1680 971 1592 833 424 725 906 1547 458 1469
1780 1251 1902 1263 574 1065 1096 1747 478 1619
1271 1363 744 1105 1346 2017 518 1679
1511 1513 1064 1495 1356 1767 808 1999
1741 1543 1134 1515 1486 1867 888 1789
1701 1943 1264 1925 1716 1748 1859
1901 1384 1775 1926 1798
2011 1444 1845 1646 1838
1484 1635 1706 1648
1544 1685 1996
1994 1875 1836
1755
1835

Mathematical Programming
1800 1049

Mathieu Functions
1247

Matrix Methods
620 354 675 1458
1598

Measurement Instruments
532

Measurement Techniques
1000 371 242 593 894 65 656 317 678 239
1090 701 712 813 1004 235 987 918 679
1420 1001 912 1003 1094 535 997 1398 1919
2030 1201 1292 1073 1494 1095 1067 1518 1779
1401 1405 1267
1571 1407

Measuring Instruments
370 371 652 653 234 235 236 1777 768
2031 803 654 535 806
993 804 805 1916
1573 1195
1335
1565
1915

Measuring Techniques
1920

Mechanical Admittance
620

Mechanical Elements
1227

Mechanical Impedance
620 1206 1059

Mechanical Systems
910 1281 1872 1957 909
1320 1849

Mechanisms
92 93 95 96
646

Membranes
1435 1436 1247 1058 129
1465

Membranes (Structural Members)
274 846

Metal Working
1660 1661 1284 916 917 138
2000

Method of Characteristics
841 974 105 266 1937

Abstract Numbers: 1-159 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Method of Intermediate Coordinate Transformation	1328 1329	Models	159
Method of Steepest Descent	1625	Model Testing	1040 1051 1052 63 1106 1698 1039
Military Aircraft	1635 1637		83 1976 1898
			1593
Military Facilities		Model Tests	285
	209		
Mines (Ordnance)	1538	Mode Shapes	
		130 251 442 123 424 125 426 307 418 109	
Minimum Weight Design		160 271 1842 333 864 225 586 687 868 519	
1082 1473	1787 1049	540 581 553 1005 1526 1817 948 1119	
1222		1330 1231 613 1315 1238 1419	
Mining Equipment		1890 1351 1323 1415 1809	
712		1411 2023	
Missile Launchers	1497	1711	
		Monorail Railways	2010
Missiles		Monte Carlo Method	1545 617 1529
330 51 1112 1173 1644	1967 1198		
1561 1332	1498	Moorings	377
Missile Silos			
1561		Motion Compensation Systems	1101 1102
Mobility Method	1587	Motorcycles	1296
Modal Analysis		Motor Trucks	2012
661 1182 303 1314 1145 506 757 108 209			
1641 1342 753 1454 1715 846 997 539		Motor Vehicle Noise	470 471 472 413 1095 166 927 878 469
1721 1922 1453 1644 1765 1146			740 1297
1941 1952 1693 1526		Motor Vehicles	1694 1695 1299
Modal Damping			
161 1803 1507 1508		Mountings	1911 642 69
Modal Methods	772		1282 1069
Modal Survey Tests	944	Mounts	262
Modal Tests	1377		
Abstract	1-150 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031		
Numbers:			
Volume 8			
Issue:	1 2 3 4 5 6 7 8 9 10 11 12		

Moving Loads

310 142 374 75 1576 1577 1578 819
862 744 1819
1134

Mufflers

452 543 1439
603

Multi-Beam Systems

451 836

Multidegree of Freedom Systems

21 762 334 1505 57 1118 969
1725

Multifrequency Oscillations

5

Multistorey Buildings

1990 901 902 1064 1065 1837 1838 1269
1731 1482

Musical Instruments

70 1795

- N -

Nacelles

403

NASTRAN (Computer Programs)

540 492 493 495 496 497 498 499
500 615 517 538
1315

Natural Frequencies

130 251 22 123 84 85 106 307 278 109
160 271 122 133 114 125 426 687 418 519
540 1031 442 153 234 675 586 817 868 1119
550 1111 1842 303 864 845 1016 857 948 1329
1330 1231 553 1224 865 1526 1447 1238 1459
1890 1351 613 1724 1005 1816 1657 1328 1619
1411 643 1025 1787 1418 1809
1531 943 1315 1817 1948
1711 1123 1415
1323 1625
1803 1815

Nature Parameter

1483

Newton-Raphson Method

757

Noise Acoustic Measurement

722

Noise Barriers

1912 1633 874 875 926
1034 1466

Noise Control

340 341 1884 637 638

Noise Generation

740 81 202 353 604 455 456 937 28 219
1030 201 302 453 1964 715 466 1597 178 739
1640 281 572 463 2004 775 776 1697 778 939
1670 461 802 623 1055 1426 1528 1149
1680 1221 1262 1283 1655 1476 1668 1489
1291 1312 1563 1675 1676 1858 1599
1381 1682 1683 1669
1671 1892 1893 1679
1681 1852

Noise Measurement

350 371 332 523 404 195 466 197 168 349
1260 411 402 593 594 405 1056 1527 698 379
721 712 803 1074 925 768 469
1571 1562 1073 1174 778 569
882 1494 918 989
1258 1259
1518 1629
1688
1978
1998

Noise Prediction

731 732 203 1055 1076 1859
891 623 1346
1291 733
1641

Abstract Numbers: 1-150 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue 1 2 3 4 5 6 7 8 9 10 11 12

Noise Reduction									
180	171	172	203	174	35	166	197	198	139
260	201	202	403	194	195	296	397	388	199
470	471	412	443	204	495	306	407	398	389
640	571	452	453	264	695	406	727	548	399
700	731	462	543	344	875	636	837	588	639
730	771	472	573	414	1035	796	877	728	729
830	1011	572	603	484	1255	926	927	768	739
920	1071	712	623	694	1475	1136	1037	838	839
940	1291	732	693	874	1665	1666	1297	878	879
1100	1381	892	733	1054	1885	1886	1467	928	1079
1230	1521	1002	873	1254	1945	1976	1477	1053	1099
1250	1961	1012	893	1524	2005	2006	1487	1628	1489
1280	1981	1072	913	1984			1627	1868	1629
1290		1292	1053				1677		1669
1960		1602	1523				1687		1719
1980		1962	1643				2007		1959
		1982	1943						1869
		2012	1963						
		1852	1983						
Noise (Sound)									
710									
Noise Source Identification									
740	1052	1213		1095	1656	1977		959	
1530		1343			1856				
1950		1643							
Noise Tolerance									
292									
1652									
Nondestructive Testing									
244									
804									
Nondestructive Testing Technique									
1782									
Nondestructive Tests									
1781									
743									
Nonlinear Analysis									
760	761		334		756				
Nonlinear Programming									
1140									
Nonlinear Response									
1080	62	3	754		276	117	538	9	
1930					1457	1798			
Nonlinear Structures									
181									
Nonlinear Systems									
950	1322		1515	96				488	
1320			1725					1358	
Nonlinear Theories									
1460	762		1505						19
Nonparametric Identification									
897									
Non-Proportional Damping									
1744									
Normal Mode Method									
126									
Normal Modes									
1330	961		124	625				608	
			614	1925					
			1024						
Nozzles									
570	1221		623					778	199
			1013					1599	
Nuclear Explosion Damage									
216									
286									
Nuclear Explosion Effects									
360	52	53							
Nuclear Explosions									
781									
782									
Nuclear Fuel Elements									
631	73	1684	1685				227		9
			313						
Nuclear Power Plants									
170	141	212	213	104			146	267	1318
1840	211	972	1693				266		1189
1860	1491	1732					1186		
	1761	1862							
	1861								
Nuclear Reaction Components									
922									
9									
Abstract Numbers:									
1-150									
180-332									
333-486									
487-623									
624-751									
752-948									
949-1117									
1118-1318									
1319-1503									
1504-1721									
1722-1871									
1872-2031									
Volume 8									
Index:									
1	2	3	4	5	6	7	8	9	10
11	12								

Nuclear Reactor Components

1414 1855 1597
1864

Nuclear Reactors

2011 1383 737 599
1863

Numerical Analysis

120 122 23 964 335 57 158 29
130 162 153 974 1647 758 129
970 978 969
1050 1008 979
1029

Nutation Damper

1114 1895 1896 1897

. O .

Oceans

1350 1349

Off-Shore Structures

680 1921 1184 1898
1720

Oil Film

670

Oil Whip Phenomena

610
1710

One-Degree-of-Freedom Systems

1850

Optimization

390 831 662 1293 214 1425 296 387
1140 1901 942 1473 634 1625 566
1490 1941

Optimum Control Theory

480 832 1279
1140

Optimum Design

1800 141 115 336 258
871 1785 1958

Organs (Biological)

1264 1058

Oscillation

1020 521 162 335 1106 1107 348 429
1030 1021 2026 1237 488 1659
1050 1911

Oscillations

3 754 826 59
1423 934

Oscillators

40 1121 242 1355 1376 17 18
1850 372 1327
752

. P .

Packaging

1190 2001 1285 1286 1288 1289

Packaging Materials

1662 1663
2002

Packing Materials

294

Panels

390 331 1833 1954 265 847 1028
391 1437 1228
1438
1458

Parachutes

1513

Parameter Identification

621 34 585 586 1878
1731 1515 1146
1965 1966

Abstract Numbers: 1-159 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Parameter Identification Techniques
2011

Parametric Excitation

845 116
646

Parametric Resonance
1272

Parametric Response

780 552
1810

Passive Isolation

1251 1542

387

Pavement Roughness

1301 1543

935 466
1195

Pavements

743 434 536 367
744
924

Pavement Thickness

743

Pendulums

10 1572 234 236 627 629
1397

Pennstocks

275

Periodic Excitation

1450 1041 752 223 465 1606 107 378 1549
1500 1181 1372 1653 1235
1371 1245

Periodic Response

310 502 2014 755 36 667 1939
1515 836 1819
1506
1596

Periodic Structures

16

Perturbation Techniques

1871

757

Perturbation Theory

1330 1331 762 423 1614 276 627
1784 1236 1817

Phase Velocity

1915

Photoelastic Analysis

1202

Photographic Techniques

872 534

Piezoelectricity

82 953

999

Piezoelectric Shakers

533

Piezoelectric Transducers

1873

File Drivers

35

File Driving

1902 1554

File Structures

1902 714
1184
1554
1764

Pins

1684 1697

Pipelines

1946

Pipes (Tubes)

650 681 682 813 1604 436 547 548 849
1410 1947 848 1229
1440 1439

Piping Systems

1230 102 103 104 105 266 267
1810 1602 214

Pistons

296

Abstract Numbers: 1-160 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Propulsion Systems

1985 1986 407

Protective Devices

1468

Protective Shelters

582

895

1648

2028

Pseudo-Shock Waves

357

Pulse Compression Techniques

1389

Pulse Excitation

1810 1462 1923

1678

Pulse Test Method

140

1915

1650

Pulse Test Techniques

1203

Pumps

141

1664 305

309

1854 595

755

1855

Pyrotechnic Shock Environment

1160 1161 1162

1158 1159

- Q -

Quasilinearization Technique

1787

Railroad Cars

1490 741 732 733 144 735 1336 598
1293 958

Railroads

462 143

Railroad Tracks

310 731 142 145 1578

Railroad Trains

461 463 145 1857 1858 1859

Railroad Vehicles

2009

Rails

1541

Rail Transportation

530

1076

920

Random Excitation

40 1181 362 73 1184 725 947 249
480 1531 752 763 1374 935 1047
970 1832 1613 1355
1140 1725

Random Response

1210 1 1532 1353 1144 125 16 38 39
1270 1434 145 58
1464

Random Vibration

511 503 1354 1635 206 37 508 1709
1321 1143 1576 507 758
1763

Rapid Transit Railways

312

Rayleigh-Ritz Method

1240 393 1509
1620

Rayleigh Waves

777

Abstract Numbers:

1-169 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue 1 2 3 4 5 6 7 8 9 10 11 12

[illegible]

[illegible]

Shear Vibration
901

Shells

1030 1381 2 113 124 395 116 687 688 689
1510 112 553 684 1615 396 737 1548 889
1610 942 1133 787 1608 1449
1820 1032 1243 1607 1788
1953

Shells of Revolution

1460 1461 273 854 555 128
855
1955

Shell Theories

687

Shipboard Equipment Response

590 591 232 1334 616 587 659
592 1494 1566 1557

Shipboard Machinery

940 1556

Ship Hulls

614 159
1714

Ship Noise

940 353 476 939
1100 913

Shipping Containers

1190 2001 1286 1287 1288 529

Ships

1871 1103 1314 1495 1496 1277 1368
1433

Ship Structures

159

Ship Vibration

750 475 476 615

Shock Absorbers

590 261 262 345 1996 1997 138
1462 1737

Shock Absorption

870 1421 294 1166 1537 528
1636

Shock Excitation

1651 1923 1775 866 787 218 539
1709

Shock Isolation

230 583
1140

Shock Response

200 111 582 823 374 1165 526 827 888 509
1470 51 822 973 824 856 1187 1358 869
1031 1812 1413 1456 1887 1538 889
1131 1469
1791

Shock Response Spectra

95 96 507
505 1356 1557
525

Shock Tests

1400 511 505 1908
2001 975

Shock Tubes

233 357 1359

Shock Tube Tests

522

Shock Wave Attenuation

1170 922

Shock Wave Propagation

50 841 822 233 534 205 216 47 48 49
790 1672 1113 824 605 1616 217 358 359
1220 1953 787 1169
827 1359
1167

Shock Wave Reflection

784

Shock Waves

330 32 175 786 357 788 219
785 1456 239

Abstract Numbers: 1-150 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

1 2 3 4 5 6 7 8 9 10 11 12

Sound Transmission
 840 131 1552 543 964 65 696 1947 399
 1350 191 963 1214 1035 766 1977 1219
 1380 1431 1345 1036 1807 1229
 1760 1066 1439
 1809

Sound Transmission Loss
 1350 1833 1034 1028 1199

Sound Wave Attenuation
 1440

Sound Waves
 380 351 542 543 24 55 696 547 1428 269
 1892 1154 715 846 1349
 1486

Spacecraft
 720 751 942 943 944 985 336 37 618 619
 1110 1111 2022 1403 1114 1315 1316 617 1109
 1500 1501 2023 1394 1395 747 1499
 1560 2024 2025 1107
 1407
 1717

Spacecraft Antennas
 1180

Spacecraft Components
 331 595 477 498 749
 1105 1377 748 1799
 1715 1718

Spacecraft Equipment
 1931 1895 1896 1897
 1997
 2027

Spacecraft Equipment Response
 1160 1161 1162 1158 509
 1159

Space Stations
 500 161 1104 1105 1106 1497 1108 479
 1715 1716 499
 1719

Specifications
 1335 1336 197
 477

Spectra
 783

Spectral Analysis
 2013

Spectral Energy Distribution
 1200 1841 1832 38 1799
 1188

Spectrum Analysis
 1760 1721 1353 1434 605 207 689
 1393 1265 1227 1379
 1547

Spectrum Analyzers
 1393 1145

Spheres
 200 1827 1459

Spherical Shells
 1611 43 124 685 856 118
 1823 1614 1825 1246
 1824 1826

Spherical Waves
 33 759

Springs
 1248

Squeeze Film Bearings
 80 1591 612 77 1899
 1590 672
 1900

Squeeze Film Dampers
 151 152

Stability
 150 11 12 13 664 265 76 337 658 79
 1810 51 442 703 704 665 956 1147 828 919
 671 1042 763 884 885 1276 1707 1128 1209
 761 863 934 955 2016 1148
 1281 954 985 1408
 1901 1114 1215
 1554 1245

Stability Analyses
 1130 1331 1332 514 585 156 157 628
 2021 764 1125 1127
 1324

Abstract Numbers: 1-150 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue 1 2 3 4 5 6 7 8 9 10 11 12

Stability Methods
751 163 164 1126 1129
1419

Stabilization
1253

Stalling
584 976 2018

Standards
1340 1651 893 1975 446 1337 1338 1339
1083 1176 1517 1518
1853 1516

Standards and Codes
1131 1002 243 957 168
1038
1628

Standing Waves
19

Statistical Analysis
1390 1471 1662 433 14 125 206 567 228
783 1155 688
1258

Statistical Energy Analysis
1729

Statistical Energy Method
1831 772 846 1317
1032

Statistical Methods
1150

Stators
1803

Steam Hammer
104 266

Steam Turbines
484 596

Steel
217 58

Steepest Descent Method
258

Steering Effects
2010 1084 1085 2009
2014

Step Response
684 676

Stick-Slip Excitation
1680 64

Stick-Slip Response
1492 647

Stiffened Plates
1621 269
1949

Stiffened Shells
1240 1612 853 1454 275 108
1453 395

Stiffening
475 846

Stiffness
713 804 76 77

Stiffness Coefficients
70 671 14 1588 979
1330 1589

Stiffness Methods
182 1033 1505

Stochastic Processes
1271 2013 1354 1725 956 1658
1841

Storage
217 238

Storage Tanks
1051 704

Strings
70 1795 668
1798

Abstract Numbers: 1-159 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Temperature Effects

231

Temperature Effects (Other Than Excitation)

1630 1662 1663

Test Data

1212

Test Equipment

600 1362 793 794 345 366 97 58 299
1020 983 984 975 536 367 288 319
1203 1204 1795 1518 749
1564 1189

Test Facilities

800 801 1092 313 1294 795 986 297 368 649
1560 811 513 1914 1295 1196 797 988 799
1501 1913 1976 1137 1068 1259
1561 1188 1559
1228
1908

Test Instrumentation

1394 795 1407 988
1395

Test Models

281 582 193 64 565 177 188 619
1031 237 238 829
1501 1497 558 1109
1741 578
1538

Test Stands

1560 1562 1776

Testing Equipment

1392 1393 1205 1227

Testing Facilities

1190 985 986

Testing Techniques

240 1 592 243 674 215 726 227 368 369
510 241 812 373 744 975 996 477 508 379
810 441 872 733 914 995 1206 747 1088 509
1020 811 992 813 1084 1635 1406 1197 1158 589
1110 1161 1132 1153 1516 1207 1198 769
1160 1162 1203 1566 1287 1228 1019
1260 1202 1213 1567 1318 1039

Abstract Numbers: 1-160 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Index: 1 2 3 4 5 6 7 8 9 10 11 12

Testing Techniques (Continued)

1500 1402 1403 1917 1568 1159
1570 1522 1463 1918 1299
1882 1783 1369
1399
1569

Testor Vehicles

324

Textile Looms

332

Theoretical Analysis

138

Thermal Excitation

121 1015
521

Thermoelasticity

1623

Thermoviscoelasticity

1531

Thermoviscoelasticity Theory

1772

Thickness Effects

158

Three Degree of Freedom Systems

1332

Three Dimensional Problems

1241 643

Thrust Bearings

255

Tiles

1715

Time-Dependent Excitation

1451 552 206 249

Time-Dependent Parameters

950 1121 1024 1325
1354

Abstract Numbers:	1-156	160-332	333-486	487-623	624-751	752-948	949-1117	1118-1318	1319-1503	1504-1721	1722-1871	1872-2031
Volume 8												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

Transportation Systems										Turbomachinery									
1150					1094				1149	610	481	482	483		485	326	1937		839
Transverse Shear Deformation Effects										2030	531	612	623		1935				2029
110	1951	122		124		556			109	1870	1291	1212							
250	1811	862		814		1496			1579		2031								
		1442							1789	Turbulence									
		1822								351	1062			394	285		577	858	1139
Trashracks										1041	1362			964					1639
										1381				1634					
Trees (Plants)										Turbulence Amplifiers									
									137										
									767	Two Degree of Freedom Systems									
Truck Engines																			
740						1686	1687		739	1724									
Truck Tires										U .									
						466													
Trucks										Ultrasonic Techniques									
530					603			1297	928	1060				1284	55				1389
1540					923			1357	1688	Unbalanced Mass Response									
Trusses																			
						1625			258	745									
Tubes										Underground Explosions									
190	31	82	73	114		106	1017	1018	19	780						356	237	238	
1170	101			1823		1016				1533						526	1167		
																1166			
Tuned Dampers										Underground Structures									
221										583						216	217	238	1029
Tunnels																1166	1167		
																1766			
Turbine Blades										Underwater Explosions									
540	831	832	1593	1214	1425				1579	1360				1534	205			1908	659
1800															805				
Turbine Components															1565				
220	1961				2004			2007		Underwater Pipelines									
Turbines																1946			
										Underwater Sound									
	1692	2003			1885	1856		1678		960	961	532	353		965	196	1547	1348	959
										1380		962	963		1155	766			
										1760		1552			1546				

Abstract Numbers: 1-159 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Underwater Sound Transmission
1152 876

Underwater Structures
1611 1612 1538 1759
1898

Urban Noise
1682 1523 1345 349

- V -

Valves
100 103 1225 676 677 298

Variable Cross Section
250 542 814 855 6 1237 8 109
840 864 1415
1620 1455

Variable Material Properties
14 8 259

Variational Methods
1231 1232 613 765 1726 1958 789

Variational Technique
124

Vehicle Response
1084 1085

Vibrating Structures
1950 825 1328 1329
1575

Vibration Absorbers
1464

Vibration Absorbers (Equipment)
558

Vibration Absorption (Equipment)
910 222 223 126 157 1279
1070 156 387

Vibration Absorption (Materials)
1384 398

Vibration Analyzers
994 989

Vibration Control
220 221 282 283 284 475 616 78 139
300 561 942 504 565 1078 329
560 731 982 584 1385 1488 1309
920 1801 1712 1224

Vibration Dampers
720 401 1542 68

Vibration Damping
220 151 1402 473 56 157 398 589
400 733 156 397 608 749
660 1633 236 748
386 1178
1926 1488

Vibration Effects
652 1555

Vibration Excitation
430 291 1173 464 135 366 447 588 719
890 1061 1373 1994 445 446 717 1278
1211 1653 1995 1338
1651

Vibration Frequencies
1873 1654

Vibration Generation
610

Vibration Isolation
230 261 232 385 546
1140 1282 1846
1590

Vibration Isolators
1433 1845 1959

Vibration Measurement
370 701 332 993 404 535 106 997 1398 379
530 532 464 1335 439
1420 1192 594 1935 1239
674
724
1174

Abstract Numbers: 1-189 180-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Vibration Reduction

1577
1847

Vibration Resonance

952 953 334 1865
1252

Vibration Response

110 21 2 393 614 15 556 257 448 309
370 71 132 493 1134 275 666 1437 538 509
1490 331 162 713 1264 435 806 1537 648 549
1580 821 272 853 1324 1325 1246 708 589
1131 492 1233 1474 1715 1936 1438 669
1241 1452 1543 1484 1875 1889
1281 1902 1583 1544 1829
1311 1733 1714 1849
1461 1823 1824

Vibration Response Spectra

724

Vibration Signatures

1075

Vibration Spectra

605

Vibration Testing

1190 1205 1206 1197
1207

Vibration Tests

510 381 1842 503 504 595 506 507 138 509
620 511 513 914 1285 536 747 508 1499
810 581 713 1564 686 1517 988 1569
1500 811 743 1156 1567 1198
2001 793 1718
1403

Vibration Tuning

1178

Vibrators

61

Vibrators (Machinery)

651 536 809
916

Vibratory Techniques

713 434 906 917
1913

Viscoelastic Damping

1385 2027 498
1848

Viscoelastic Foundations

1386 1578 979

Viscoelasticity

1610 1906

Viscoelasticity Theory

765

Viscoelastic Media

231 1385 977 978

Viscoelastic Medium

1768

Viscoelastic Properties

1580 551 1132 294 1607
1812

Viscoplastic Properties

1952 1413 1607

Viscosity Effects

118

Viscous Damping

661 1412 93 164 1375 1376 327 8
1731 1822 253 1744 1927 1848
1791 1767

Vortex-Induced Vibration

1940

Vortex Noise

1352 1275

Vortex Shedding

60 1551 1182 364 825 226 27 1938 59
1030 544 1215 976 1758
1184

Abstract Numbers: 1-160 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

. W .											
Walls						Welded Joints					
133						142					
286 1067 1068 709						Wheels					
656 1448 769						741					
1816						1299					
Water						Wheel Shimmy					
17						1253					
Water Hammer						Whirling					
267						672 745 78					
Water Waves						Winches					
1360 1101 83 1898						915					
1871						Wind-Induced Excitation					
Wave Absorption						480 1271 222 353 834 1065 176 1857 688 689					
1739						1840 1631 1182 363 884 606 1208 1989					
Wave Diffraction						1272 433 1244 896 1268					
192 23 1904 645 189						1692 1183 1974 1216					
352 1903 1739						1273 2024 1423					
Wave Equations						Windows					
1154 1504						1611 1448					
Waveguide Analysis						Wind Tunnels					
1495						800 802 1563 874 796 1807 368 369					
Wave Propagation						1910 1912 798 799					
231 192 4 55 6 777 8 999						1669 1909					
791 1892 1594 1496 977 1008 1349						Wind Tunnel Tests					
951 1784 1876 1757 1218 1379						240 281 402 565 886 887 428 479					
1736						1020 561 422 1985 1046 987 558					
Wave Reflection						1040 1021 642 1106 1107 568					
520 547 759						1041 1062 1986 1387 788					
Wave Transmission						1311 1112 1497 1108					
759						1601 1352 1917 1988					
Wear						1911 1972					
325 99						Wing Stores					
Weighted Residual Technique						560 1051 422 423 424 425 426 417 418					
1598						1971 562 563 704 427 428					
						1173 1917 1198					
						Wobble					
						546					
						Woodworking Machines					
						302					

Abstract Numbers: 1-159 160-332 333-486 487-623 624-751 752-948 949-1117 1118-1318 1319-1503 1504-1721 1722-1871 1872-2031

Volume 8

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

PERIODICALS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
ACTA MECHANICA SPRINGER-VERLAG NEW YORK INC., 175 FIFTH AVE., NEW YORK, N.Y. 10010	Acta Mech.	BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS JAPAN SOCIETY OF MECHANICAL ENGINEERS, NIMON KIKAKO KYOKAI BLDG., 1-24, 4-CHOME, AKASAKA, MINATO-KU, TOKYO, JAPAN	Bull. JSME
ACUSTICA S. HIRZEL VERLAG, 7 STUTTGART N, BERKENWALDSTR. 185A, POSTF 347, GERMANY	Acustica	BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA BRUCE A. BOLT, BOX 826, BERKELEY, CALIF. 94706	Bull. Seismol. Soc. Amer.
AERONAUTICAL JOURNAL ROYA. AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, LONDON W1V 0BQ, ENGLAND	Aeronaut. J.	CIVIL ENGINEERING (NEW YORK) ASCE PUBLICATIONS OFFICE 345 E. 45TH ST., UNITED ENGINEERING CENTER, NEW YORK, N.Y. 10017	Civ. Engr. (N.Y.)
AERONAUTICAL QUARTERLY ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, LONDON W1V 0BQ, ENGLAND	Aeronaut. Quart.	CLOSED LOOP MIT SYSTEMS CORP. P.O. BOX 24012 MINNEAPOLIS, MINN. 55424	Closed Loop
AERONAUTICAL SOCIETY OF INDIA - JOURNAL SHRI R. N. KATHJU 13-B, INDRAPRASTHA ESTATE, RING RD., NEW DELHI 1, INDIA	Aeronaut. Soc. India J.	COMPUTERS AND STRUCTURES PERGAMON PRESS INC., MAXWELL HOUSE, FAIRVIEW PARK, ELMSFORD, NEW YORK 10523	Computers and Struc.
AIAA JOURNAL AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, 1280 AVE. AMERICAS, NEW YORK, N.Y. 10019	AIAA J.	DESIGN NEWS CAHNS PUBLISHING CO., INC. 221 COLUMBUS AVE. BOSTON, MASS. 02116	Design News
APPLIED MATHEMATICS AND MECHANICS (English Translation of Prikladnaya Matematika i Mekhanika) PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC. 44-01 21ST ST., NEW YORK, N.Y. 11101	Appl. Math Mech. (PMM)	DIESEL AND GAS TURBINE PROGRESS DIESEL ENGINES, INC. P.O. BOX 7406 MILWAUKEE, WISC. 53213	Diesel and Gas Turbine Progress
ARCHIVE FOR RATIONAL MECHANICS AND ANALYSIS SPRINGER-VERLAG NEW YORK INC. 175 FIFTH AVE., NEW YORK, N.Y. 10010	Archive Rational Mech. Anal.	ENGINEERING MATERIALS AND DESIGN IPC INDUSTRIAL PRESS LTD., 33-40 BOWLING GREEN LANE, LONDON EC1R, ENGLAND	Engr. Matl. Des.
ARCHIWUM MECHANIKI STROSOWANEJ EXPORT AND IMPORT ENTERPRISE RUCH, UL. WRONIA 23, WARSAW, POLAND	Arc. Mech. Strosowanej	ENVIRONMENTAL QUARTERLY ENVIRONMENTAL PUBLICATIONS, INC., 262-46 LEEDS RD., LITTLE NECK, N.Y. 11362	Environ. Quart.
AUTOMOBILE ENGINEER IPC TRANSPORT PRESS LTD., DORSET HOUSE, STAMFORD ST., LONDON SE1, ENGLAND	Auto. Engr.	ENVIRONMENTAL SCIENCE AND TECHNOLOGY AMERICAN CHEMICAL SOCIETY 1155 16TH ST., N.W. WASHINGTON, D.C. 20036	Environ. Sci. Tech.
AUTOMOBILTECHNISCHE ZEITSCHRIFT FRANCKH'SCHE VERLAGSHANDLUNG ABTEILUNG TECHNIK, 7 STUTTGART 1, PFIZERSTRASSE 5-7, GERMANY	Automobil- tech. Z.	EXPERIMENTAL MECHANICS SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS, 21 BRIDGE SQ., WESTPORT, CONN. 06880	Exptl. Mech.
BALL BEARING JOURNAL (English Edition) AKTIEBOLAGET SVENSKA KULLAGERFABRIKEN, GOTENBORO, SWEDEN	Ball Bearing J.	FORSCHUNG IM INGENIEURWESEN VEREIN DEUTSCHER INGENIEUR, GMBH POSTFACH 1139, GRAF-HECKE STR. 84, 4 DUESSELDORF 1, GERMANY	Forsch. Ingenieurw.
BAUINGENIEUR SPRINGER-VERLAG NEW YORK INC., 175 FIFTH AVE., NEW YORK, N.Y. 10010	Bauingen- ieur	GEOTECHNIQUE INSTITUTION OF CIVIL ENGINEERS GREAT GEORGE ST. 7 WESTMINSTER, LONDON, SWP 3AA ENGLAND	Geotech.
BROWN BOVERI REVIEW BROWN BOVERI AND CO., LTD. CH-5401, BADEN, SWITZERLAND	Brown Boveri Rev.	HIGH-SPEED GROUND TRANSPORTATION JOURNAL HIGH-SPEED GROUND TRANSPORTATION JOURNAL, P.O. BOX 4824, DUKE STATION, DURHAM, N.C. 27706	High-Speed Ground Transp. J.
BULLETIN DE L'ACADEMIE POLONAISE DES SCIENCES, SERIES DES SCIENCES TECHNIQUES EXPORT AND IMPORT ENTERPRISE RUCH, UL. WRONIA 23, WARSAW, POLAND	Bull. Acad. Polon. Sci., Ser. Sci. Tech.	IBM JOURNAL OF RESEARCH AND DEVELOPMENT INTERNATIONAL BUSINESS MACHINES CORP., ARMONK, N.Y. 10504	IBM J. Res. Dev.
BULLETIN OF THE FACULTY OF ENGINEERING, YOKAHOMA NATIONAL UNIVERSITY YOKAHOMA NATIONAL UNIVERSITY, OHKA-MACHI, MINAMI-KU YOKAHOMA, JAPAN	Bull. Fac. Engr. Yokahoma Natl. Univ.	ICP QUARTERLY INTERNATIONAL COMPUTER PROGRAM, INC., 2511 EAST 45TH ST., INDIANAPOLIS, IND.	ICP Quart.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
INDUSTRIAL RESEARCH DUN-DONNELLEY PUBLISHING CORP. 222 S. RIVERSIDE PLAZA CHICAGO, ILL. 60608	Indus. Res.	ISRAEL JOURNAL OF TECHNOLOGY WEIZMANN SCIENCE PRESS OF ISRAEL, BOX 801, JERUSALEM, ISRAEL	Israel J. Tech.
INGENIEUR-ARCHIV SPRINGER-VERLAG NEW YORK INC., 175 FIFTH AVE., NEW YORK, N.Y. 10010	Ing. Arch.	JOURNAL DE MECANIQUE GAUTHIER-VILLARS, 55 QUAI DES GRANDS AUGUSTINES, PARIS 6, FRANCE	J. de Mecanique
INSTITUTION OF MECHANICAL ENGINEERS, (LONDON), PROCEEDINGS INSTITUTION OF MECHANICAL ENGINEERS 1 BIRDCAGE WALK, WESTMINSTER, LONDON SW1, ENGLAND	Instn. Mech. Engr. Proc.	JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA AMERICAN INSTITUTE OF PHYSICS, 335 E. 45TH ST., NEW YORK, N.Y. 10010	J. Acoust. Soc. Amer.
INSTITUTION OF NAVAL ARCHITECTS, TRANS- ACTIONS	Instn. Naval Arch., Trans	JOURNAL OF AIRCRAFT AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, 1290 AVE. AMERICAS, NEW YORK, N.Y. 10019	J. Aircraft
INSTRUMENTATION MONEYWELL, INC. FORT WASHINGTON, PA. 19034	Instr.	JOURNAL OF THE AMERICAN CONCRETE INSTITUTE AMERICAN CONCRETE INSTITUTE P.O. BOX 4754, REDFORD STATION, DETROIT, MICH. 48219	J. Amer. Concrete Inst.
INTERNATIONAL CONGRESS ON ACOUSTICS	Intl. Cong. Acoust.	JOURNAL OF THE AMERICAN HELICOPTER SOCIETY AMERICAN HELICOPTER SOCIETY, INC., 30 E. 42ND ST., NEW YORK, N.Y. 10017	J. Amer. Helicopter Soc.
INTERNATIONAL JOURNAL OF CONTROL TAYLOR AND FRANCIS LTD. 10-14 MACKLIN ST. LONDON WC2B 9NF, ENGLAND	Intl. J. Control	JOURNAL OF THE AUDIO ENGINEERING SOCIETY AUDIO ENGINEERING SOCIETY, 104 LIBERTY ST., UTICA, N.Y. 13502	J. Audio Engr. Soc.
INTERNATIONAL JOURNAL OF EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS JOHN WILEY AND SONS, LTD., 605 THIRD AVE., NEW YORK, N.Y. 10016	Intl. J. Earthquake Engr. Struc. Dynam.	JOURNAL OF AUTOMOTIVE ENGINEERING TWO PENNSYLVANIA PLAZA NEW YORK, N.Y. 10001	J. Automat. Engr.
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Intl. J. Engr. Sci.	JOURNAL OF COMPOSITE MATERIALS TECHNOMIC PUBLISHING CO., INC. 750 SUMMER ST., STAMFORD, CONN. 06901	J. Compos- ite Matl.
INTERNATIONAL JOURNAL OF FRACTURE NOORDHOFF INTERNATIONAL PUBLISHING CO. P.O. BOX 26, LEIDEN NETHERLANDS	Intl. J. Fract.	JOURNAL OF ENGINEERING MATHEMATICS NOORDHOFF INTERNATIONAL PUBLISHING CO. P.O. BOX 26, LEIDEN NETHERLANDS	J. Engr. Math.
INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Intl. J. Mach. Tool Des. Res.	JOURNAL OF ENVIRONMENTAL SCIENCES INSTITUTE OF ENVIRONMENTAL SCIENCES, 940 E. NORTHWEST HIGHWAY, MT. PROSPECT, ILL. 60056	J. Environ. Sci.
INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Intl. J. Mech. Sci.	JOURNAL OF FLUID MECHANICS CAMBRIDGE UNIVERSITY PRESS, 32 E. 57TH ST., NEW YORK, N.Y. 10022	J. Fluid Mech.
INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Intl. J. Nonlinear Mech.	JOURNAL OF THE FRANKLIN INSTITUTE FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA, PHILADELPHIA, PA 19103	J. Franklin Inst.
INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING JOHN WILEY AND SONS, LTD., 605 THIRD AVE., NEW YORK, N.Y. 10016	Intl. J. Numer. Methods Engr.	JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA SCIENCE HOUSE, GLOUCESTER AND ESSEX ST. STONE, AUSTRALIA 2000	J. Instn. Engr., Australia
INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101		JOURNAL OF THE INSTITUTION OF ENGINEERS (INDIA), MECHANICAL ENGINEERING DIVISION INSTITUTION OF ENGINEERS (INDIA), 8 GOKHALE RD., CALCUTTA 20, INDIA	J. Instn. Engr. (India), Mech. Engr. Div.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF MECHANICAL ENGINEERING SCIENCE INSTITUTION OF MECHANICAL ENGINEERS, 1 BIRDCAVE WALK, WESTMINSTER, LONDON SW1, ENGLAND	J. Mech. Engr. Sci.	MECANIQUE APPLIQUEE EDITIONS DE L'ACADEMIE DE LA REPUBLIQUE SOCIALISTE DE ROUMANIE 3 BIS, STR. GUTENBERG, BUCAREST, ROMANIA	Mecanique Appliquee
JOURNAL OF MECHANICAL LABORATORY OF JAPAN (English Edition) THE GOVERNMENT MECHANICAL LAB., AGENCY OF INDUSTRIAL SCIENCE AND TECHNOLOGY, 4-12 IGUSA SUGINAMI-KU, TOKYO, JAPAN	J. Mech. Lab. Japan	MEASUREMENTS AND DATA MEASUREMENTS AND DATA CORP. 1007 WASHINGTON RD. PITTSBURGH, PA. 15220	Meas. and Data
JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST. NEW YORK, N.Y. 11101	J. Mech. Phys. Solids	MECCANICA PERGAMON PRESS, MAXWELL SCIENTIFIC INTERNATIONAL, INC., 44-01 21ST ST., NEW YORK, N.Y. 11101	Meccanica
JOURNAL OF PHYSICS E. (SCIENTIFIC INSTRUMENTS) AMERICAN INSTITUTE OF PHYSICS, 335 E. 45TH ST., NEW YORK, N.Y. 10017	J. Phys. E. (Sci. Instr.)	MECHANICAL ENGINEERING AMERICAN SOCIETY OF MECHANICAL ENGINEERS, 345 E. 47TH ST., NEW YORK, N.Y. 10017	Mech. Engr.
JOURNAL OF RESEARCH OF THE NATIONAL BUREAU OF STANDARDS, SECTION C, ENGINEERING AND INSTRUMENTATION SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE WASHINGTON, D.C. 20402	J. Res. Natl. Bur. Std. Sect. C., Engr. Instr.	MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY KYOTO UNIVERSITY, KYOTO, JAPAN	Mem. Fac. Engr., Kyoto Univ.
JOURNAL OF SHIP RESEARCH SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, 20TH AND NORTHAMPTON ST., EASTON, PA.	J. Ship Res.	MEMOIRES OF THE FACULTY OF ENGINEERING, NAGOYA UNIVERSITY LIBRARY, NAGOYA UNIVERSITY THE FACULTY OF ENGINEERING, FURO-CHO, CHIKUSA-KU, NAGOYA, JAPAN	Mem. Fac. Engr., Nagoya Univ.
JOURNAL OF THE SOCIETY OF ENVIRONMENTAL ENGINEERS THE MODOG PRESS LTD., 8 CONDUIT ST., LONDON W1R9TG, ENGLAND	J. Soc. Environ. Engr.	MESURES, REGULATION, AUTOMATISME ILIFFE - NTP, INC. 300 E. 42ND ST., NEW YORK, N.Y. 10017	Meas. Regul. Automat.
JOURNAL OF SOUND AND VIBRATION ACADEMIC PRESS, 111 FIFTH AVE., NEW YORK, N.Y. 10019	J. Sound Vib.	MIDWESTERN CONFERENCE ON SOLID MECHANICS, PROCEEDINGS	Midw. Conf. Solid Mech., Proc.
JOURNAL OF SPACECRAFT AND ROCKETS AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, 1200 AVE. AMERICAS, NEW YORK, N.Y. 10019	J. Space- craft and Rockets	MTZ MOTORTECHNISCHE ZEITSCHRIFT FRANCKH'SCHE VERLAGSHANDLUNG 7 STUTTGART 1, PFIZERSTRASSE 5-7, GERMANY	MTZ Motor- tech. Z.
JOURNAL OF TESTING AND EVALUATION AMERICAN SOCIETY FOR TESTING & MATERIALS 1918 RACE ST. PHILADELPHIA, PA. 19103	J. Test Eval.	NATIONAL RESEARCH COUNCIL OF CANADA, DIVISION OF BUILDING RESEARCH, BIBLIOGRAPHY	Natl. Res. Council Div. Bldg. Res. Bibliogr.
JPL QUARTERLY TECHNICAL REVIEW JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE TECHNOLOGY, 4800 OAK GROVE DRIVE, PASADENA, CALIF. 91103	JPL Quart. Tech. Rev.	NAVAL ENGINEERS JOURNAL AMERICAN SOCIETY OF NAVAL ENGINEERS, INC., SUITE 807 CONTINENTAL BLDG., 1012 14TH ST., N.W., WASHINGTON, D.C. 20006	Naval Engr. J.
LUBRICATION ENGINEERING AMERICAN SOCIETY OF LUBRICATION ENGINEERS, 838 BUSSE HIGHWAY, PARK RIDGE, ILL. 60068	Lubric. Engr.	NEW ZEALAND ENGINEERING TECHNICAL PUBLICATIONS LTD., C.P.O. 3047, WELLINGTON, NEW ZEALAND	N.Z. Engr.
MACHINE DESIGN PENTON PUBLISHING CO., PENTON BLDG. CLEVELAND, OHIO 44113	Mech. Des.	NOISE CONTROL AND VIBRATION REDUCTION TRADE AND TECHNICAL PRESS LTD., CROWN HOUSE, MORDEN, SURREY, ENGLAND	Noise Control and Vib. Reduction
MASCHINEBAUTECHNIK VEB VERLAG TECHNIK, ORANIEBURGER STR. 13/14, 102 BERLIN, E. GERMANY	Maschinen- bautechnik	NOISE CONTROL ENGINEERING RAY W. HERRICK LABS. PURDUE UNIV. WEST LAFAYETTE, IND. 47907	Noise Control Engr.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
NUCLEAR ENGINEERING AND DESIGN NORTH HOLLAND PUBLISHING CO., P.O. BOX 3489 AMSTERDAM, THE NETHERLANDS	Nucl. Engr. Des.	PROCEEDINGS OF THE INSTITUTE OF ENVIRONMENTAL SCIENCES INSTITUTE OF ENVIRONMENTAL SCIENCES 940 E. NORTHWEST HIGHWAY MT. PROSPECT, ILL. 60056	Proc. Inst. Environ. Sci.
OIL AND GAS J. THE PETROLEUM PUBLISHING CO. 211 S. CHEYENNE TULSA, OKLA. 74101	Oil and Gas J.	PROCESS DESIGN CAHNERS PUBLISHING CO., INC. 221 COLUMBUS AVE. BOSTON, MASS. 02116	Process Des.
PACKAGE ENGINEERING PACKAGE ENGINEERING 5 S. WABASH AVE., CHICAGO, ILL. 60603	Package Engr.	PRODUCT ENGINEERING (NEW YORK) MC GRAW-HILL BOOK CO., 330 W. 42ND ST., NEW YORK, N.Y.	Product Engr. (N.Y.)
POLISH ACADEMY OF SCIENCES, INSTITUTE OF FUNDAMENTAL TECHNICAL RESEARCH PROCEEDINGS OF VIBRATION PROBLEMS INSTYTUT PODSTAWOWYCH PROBLEMOW, TECHNIKI PAN, WARSAW UI, SWIETOKRZYSKA 21, WARSAW, POLAND	Pol. Acad. Sci., Inst. Fund. Tech. Res., Proc. Vib. Probl.	QUARTERLY OF APPLIED MATHEMATICS AMERICAN MATHEMATICAL SOCIETY, P.O. BOX 6248, PROVIDENCE, R. I. 02904	Quart. Appl. Math.
POWER TRANSMISSION DESIGN INDUSTRIAL PUBLISHING CO., DIVISION OF PITTMAN CORP., 812 HURON RD., CLEVELAND, OHIO 44113	Power Transm. Des.	QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS OXFORD UNIVERSITY PRESS, PRESS RD., NEASDEN, LONDON NW10, ENGLAND	Quart. J. Mech. Appl. Math.
PROCEEDINGS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS PUBLICATIONS OFFICE, ASCE, UNITED ENGINEERING CENTER, 345 E. 47TH ST., NEW YORK, N.Y. 10017		REVIEW OF SCIENTIFIC INSTRUMENTS AMERICAN INSTITUTE OF PHYSICS, 335 E. 45TH ST., NEW YORK, N.Y. 10017	Rev. Sci. Instr.
JOURNAL OF THE CONSTRUCTION DIVISION	ASCE J. Constr. Div.	RUSSIAN ENGINEERING JOURNAL (English Translation of Vestnik Mashinostroeniya) PRODUCTION ENGINEERING RESEARCH ASSOC., MELTON MOWBRAY, LEICESTERSHIRE, ENGLAND	Russ. Engr. J.
JOURNAL OF THE ENGINEERING MECHANICS DIVISION	ASCE J. Engr. Mech. Div.	SAE PREPRINTS SOCIETY OF AUTOMOTIVE ENGINEERS, TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001	SAE Prepr.
JOURNAL OF THE ENVIRONMENTAL ENGINEERING DIVISION	ASCE J. Environ. Engr. Div.	SAE TRANSACTIONS SOCIETY OF AUTOMOTIVE ENGINEERS, TWO PENNSYLVANIA PLAZA, NEW YORK, N.Y. 10001	SAE Trans.
JOURNAL OF THE HYDRAULICS DIVISION	ASCE J. Hydraul. Div.	SHIPBUILDING AND MARINE ENGINEERING INTERNATIONAL WHITEHALL TECHNICAL PRESS, LTD. WROTHAM PLACE, WROTHAM, SEVENOAKS, KENT, ENGLAND	Shipbldg. Marine Engr. Int.
JOURNAL OF THE GEOTECHNICAL ENGINEERING DIVISION	ASCE J. Geotech. Engr. Div.	SIAM JOURNAL ON APPLIED MATHEMATICS SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, 33 S. 17TH ST., PHILADELPHIA, PA 19103	SIAM J. Appl. Math.
JOURNAL OF THE IRRIGATION AND DRAINAGE DIVISION	ASCE J. Irrig. Drain. Div.	SIAM JOURNAL ON NUMERICAL ANALYSIS SOCIETY FOR INDUSTRIAL AND APPLIED MATHEMATICS, 33 S. 17TH ST., PHILADELPHIA, PA. 19103	SIAM J. Numer. Anal.
JOURNAL OF THE POWER DIVISION	ASCE J. Power Div.	SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, NEW YORK, TRANSACTIONS SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, 20TH AND NORTHAMPTON ST. EASTON, PA.	Soc. Naval Architects Marine Engr., Trans.
JOURNAL OF THE SANITARY ENGINEERING DIVISION	ASCE J. Sanit. Div.		
JOURNAL OF THE SOIL MECHANICS AND FOUNDATIONS DIVISION	ASCE J. Soil Mech. Found. Div.		
JOURNAL OF THE STRUCTURAL DIVISION	ASCE J. Struc. Div.		
JOURNAL OF THE WATERWAYS, HARBORS, AND COASTAL ENGINEERING DIVISION	ASCE J. Waterways Harbors and Coastal Engr. Div.		
TRANSPORTATION ENGINEERING JOURNAL	ASCE Transp. Engr. J.		

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
SOVIET APPLIED MECHANICS (English Translation of Prikladnaya Mekhanika) FARADAY PRESS, 84 FIFTH AVE., NEW YORK, N.Y. 10011	Sov. Appl. Mech.	TRANSACTIONS OF THE INSTITUTION ENGINEERS AND SHIPBUILDERS IN SCOTLAND W. R. STEWART (ED.) 183 BATH ST., 7 GLASGOW, C2, SCOTLAND	Trans. Instr. Engr. Shipbldg. Scotland
SOVIET PHYSICS, ACOUSTICS (English Translation of Akusticheski Zhurnal) AMERICAN INSTITUTE OF PHYSICS, 333 E. 45TH ST., NEW YORK, N.Y. 10017	Sov. Phys. Acoust.	TRANSACTIONS OF THE INSTRUMENT SOCIETY OF AMERICA INSTRUMENT SOCIETY OF AMERICA, 400 STANDIX ST., PITTSBURGH, PA 15222	Trans. Instr. Soc. Amer.
STRUCTURAL ENGINEER INSTITUTION OF STRUCTURAL ENGINEERS, 11 UPPER BELGRAVE ST., LONDON SW1, ENGLAND	Struc. Engr.	TRANSACTIONS OF THE NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS NORTH EAST COAST INSTITUTION OF ENGINEERS, BOLBEC HALL, NEWCASTLE UPON TYNE 1, ENGLAND	Trans. North East Coast Inst. Engr. Shipbldg.
S/V, SOUND AND VIBRATION ACOUSTIC PUBLICATIONS INC., 27101 E. OVIAT RD., BAY VILLAGE, OHIO 44140	S/V, Sound Vib.	ULTRASONICS ILIFFE SCIENCE AND TECHNOLOGY PUBLICATIONS, INC., 300 E. 42ND ST., NEW YORK, N.Y. 10017	Ultrasonics
TECHNICAL REPORTS OF THE OSAKA UNIVERSITY FACULTY OF TECHNOLOGY, OSAKA UNIVERSITY, MIYAKOJIMA, OSAKA, JAPAN	Tech. Rept. Osaka Univ.	UNITED STATES CONGRESS ON APPLIED MECHANICS	U.S. Cong. Appl. Mech.
TECHNIK (BERLIN) VEB VERLAG TECHNIK, 102 BERLIN, ORANISENBURGER STR. 12/14, GERMANY	Technik (Berlin)	UNITED STATES NAVAL RESEARCH LABORATORIES, THE SHOCK AND VIBRATION BULLETIN SHOCK AND VIBRATION INFORMATION CENTER, NAVAL RESEARCH LAB., WASHINGTON, D.C. 20374	U.S. Naval Res. Lab., Shock Vib. Bull.
TECHNOLOGY REPORTS OF THE TOHOKU UNIVERSITY, SENDAI, JAPAN FACULTY OF ENGINEERING, TOHOKU UNIVERSITY SENDAI, JAPAN	Tech. Rept. Tohoku Univ.	VDI FORSCHUNGSZEPH VEREIN DEUTSCHER INGENIEUR GMBH POSTFACH 1139, GRAF-RECKE STR. 84, 4 DUESSELDORF 1, GERMANY	VDI Fachungsheft
TRANSACTIONS OF THE AMERICAN SOCIETY OF LUBRICATING ENGINEERS ACADEMIC PRESS, 111 FIFTH AVE., NEW YORK, N.Y. 10017	Trans. Amer. Soc. Lubric. Engr.	VDI ZEITSCHRIFT VEREIN DEUTSCHER INGENIEUR GMBH POSTFACH 1139, GRAF-RECKE STR. 84, 4 DUESSELDORF 1, GERMANY	VDI Z.
TRANSACTIONS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS UNITED ENGINEERING CENTER 348 E. 47TH ST., NEW YORK, N.Y. 10017	Trans. Amer. Soc. Lubric. Engr.	VEHICLE SYSTEMS DYNAMICS SWETS AND ZEITLINGER N.V. PUBLISHING DEPT. 347 B HERREWEG LISSE, NETHERLANDS	Vehicle Syst. Dyn.
JOURNAL OF APPLIED MECHANICS	J. Appl. Mech., Trans. ASME	WORLD CONGRESS ON APPLIED MECHANICS	World Cong. Appl. Mech.
JOURNAL OF BASIC ENGINEERING	J. Basic Engr., Trans. ASME	ZEITSCHRIFT FUR ANGEWANDTE MATHMATIK UND MECHANIK AKADEMIE VERLAG GMBH 108 BERLIN, LEIPZIGER STR. 34, GERMANY	Z. Angew.
JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT, AND CONTROL	J. Dyn. Syst., Meas. and Control, Trans. ASME	ZEITSCHRIFT FUR FLUGWISSENSCHAFTEN VEREIN DEUTSCHER INGENIEUR GMBH POSTFACH 1139, GRAF-RECKE STR. 84, 4 DUESSELDORF 1, GERMANY	Z. Flugwiss
JOURNAL OF ENGINEERING FOR INDUSTRY	J. Engr. Indus., Trans. ASME		
JOURNAL OF ENGINEERING MATERIALS AND TECHNOLOGY	J. Engr. Metl. Tech. Trans. ASME		
JOURNAL OF ENGINEERING FOR POWER	J. Engr. Power, Trans. ASME		
JOURNAL OF FLUIDS ENGINEERING	J. Fluids Engr., Trans. ASME		
JOURNAL OF HEAT TRANSFER	J. Heat Transfer, Trans. ASME		
JOURNAL OF LUBRICATION TECHNOLOGY	J. Lubric. Tech., Trans. ASME		

CALENDAR			
MEETING	DATE	LOCATION	CONTACT
Automotive Engineering Congress and Exposition (SAE Annual Meeting), SAE Symposium on Biodynamic Models and Their Applications, CHABA of NAS-NRC	1977 FEB		
	28-4	Detroit, MI	SAE Hq.
	15-17	Dayton, OH	G. Thomas Collins, Univ. of Dayton Dayton, OH 45469
Gas Turbine Conference and Products Show, ASME Joint Railroad Conference, IEEE/ASME	MAR		
	27-31	Philadelphia, PA	ASME Hq.
	30-2	Washington, D.C.	IEEE Hq.
American Power Conference, Ill. Inst. Tech. Design Engineering Conference and Show, ASME Mini-Conference on Transportation Diesel and Gas Engine Power Conference and Exhibit, ASME IES Annual Meeting International Conference - Tribology	APR		
	18-20	Chicago, IL	R.A. Budenholzer, Dir. APC c/o IIT, 10 W 35th St. Chicago, IL 60616
	18-21	New York, NY	ASME Hq.
	19-21	Ann Arbor, MI	Highway Safety Research Institute The University of Michigan Ann Arbor, MI 48109 Tele. (313) 764-2168
	24-26	Dallas, TX	ASME Hq.
	24-27	Los Angeles, CA	IES Hq.
	April	Cambridge, MA	Lt. R.S. Miller, Code 211 Office of Naval Research Ballston Tower No. 1 Arlington, VA 22117 Tele. 692-4421
31st Annual Technical Conference, ASQC 93rd Meeting of the Acoustical Society of America Structures, Structural Dynamics and Materials Conference, AIAA	MAY		
	16-18	Philadelphia, PA	R.W. Sheerman, ASQC Hq.
	17-20	State College, PA	J. C. Johnson, Chairman, ASA
	May		AIAA Hq.
Fuels and Lubricants Meeting, SAE Applied Mechanics Conference, ASME Lubrication Symposium, ASME	JUNE		
	7-9	Tulsa, OK	SAE Hq.
	14-16	New Haven, CT	ASME Hq.
	June	St. Louis, MO	ASME Hq.

CALENDAR			
MEETING	DATE	LOCATION	CONTACT
Vibrations Conference, ASME	1977 SEPT 26-28	Chicago, IL	ASME Hq.

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS:	American Federation of Information Processing Societies 210 Summit Ave., Montvale, N.J. 07645	CCCCAM:	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada
AGMA:	American Gear Manufacturers Association 1330 Mass. Ave., N.W. Washington, D.C.	IEEE:	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, N.Y. 10017
AIAA:	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, N.Y. 10019	IES:	Institute Environmental Sciences 940 E. Northwest Highway Mt. Prospect, Ill. 60056
AICHE:	American Institute of Chemical Engineers 345 E. 47th St. New York, N.Y. 10017	IFTOMM:	International Federation for Theory of Machines and Mechanisms, US Council for TMM, c/o Univ. Mass., Dept. ME, Amherst, Mass. 01002
AREA:	American Railway Engineering Association 59 E. Van Buren St. Chicago, Ill. 60605	INCE:	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch, Poughkeepsie, N.Y. 12603
AHS:	American Helicopter Society 30 E. 42nd St. New York, N.Y. 10017	ISA:	Instrument Society of America 400 Stanwix St., Pittsburgh, Pa. 15222
ARPA:	Advanced Research Projects Agency	ONR:	Office of Naval Research Code 40084, Dept. Navy, Arlington, Va. 22217
ASA:	Acoustical Society of America 335 E. 45th St. New York, N.Y. 10017	SAE:	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, Pa. 15096
ASCE:	American Society of Civil Engineers 345 E. 45th St. New York, N.Y. 10017	SEE:	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, England
ASME:	American Society of Mechanical Engineers 345 E. 47th St. New York, N.Y. 10017	SESA:	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, Conn. 06880
ASNT:	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, Ill. 60202	SNAME:	Society of Naval Architects and Marine Engineers, 74 Trinity Pl. New York, N.Y. 10006
ASQC:	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, Wis. 53203	SVIC:	Shock and Vibration Information Center Naval Research Lab., Code 8404 Washington, D.C. 20375
ASTM:	American Society for Testing and Materials 1916 Race St. Philadelphia, Pa. 19103	URSI-USNC:	International Union of Radio Science - US National Committee c/o MIT Lincoln Lab., Lexington, Mass. 02173

